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QUAIN'S ANATOMY

MYOLOGY

QUAIN'S ELEMENTS OF ANATOMY

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QUAIN'S ELEMENTS OF ANATOMY

ELEVENTH EDITION

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IN FOUR VOLUMES

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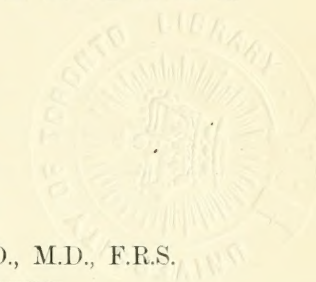
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P R E F A C E

THE present book constitutes the second part of the fourth volume of the eleventh edition of "Quain's Anatomy." Its appearance has been long delayed owing to the interruption of the work by the European War of 1914-18. In 1914 and 1915 all the new illustrations were drawn from special dissections made for the purpose, and the volume was intended to include an account of the heart and vessels, for which figures were also prepared. After it was possible to resume work on the preparation of the volume, the expenses of printing and the quite prohibitive cost of reproducing the illustrations further delayed its issue. It also appeared that there was little need for another ordinary text-book on the muscles and vessels in view of the excellent books available to the medical student, while much attention had been directed to the muscles as the result of the surgical experience of the war. It was therefore determined to make a new start and to elaborate the portion on the muscles into a special volume dealing rather more in detail with the muscular system as a whole. This decision was fortified by the consideration that there seemed need for a treatise which summarised the large amount of work which has been done in the last twenty-five years on the morphology of the muscles.

All the sections dealing with the action of the muscles throughout the book, except the paragraphs on the actions of the facial, ocular, and respiratory muscles, are the work of Professor Thomas Walmsley, and I am greatly indebted to him for this valuable assistance. To him and to Dr Matthew Young I have also to render acknowledgment for much valued help in the preparation of special dissections of the muscles. The new illustrations are from the very skilful and faithful pencil of Mr A. K. Maxwell, and I have to thank him warmly for the interest he took in the work. I am also indebted to Dr D. M. Blair and Dr R. S. Weir for reading proofs and preparing the index.

THOMAS H. BRYCE.

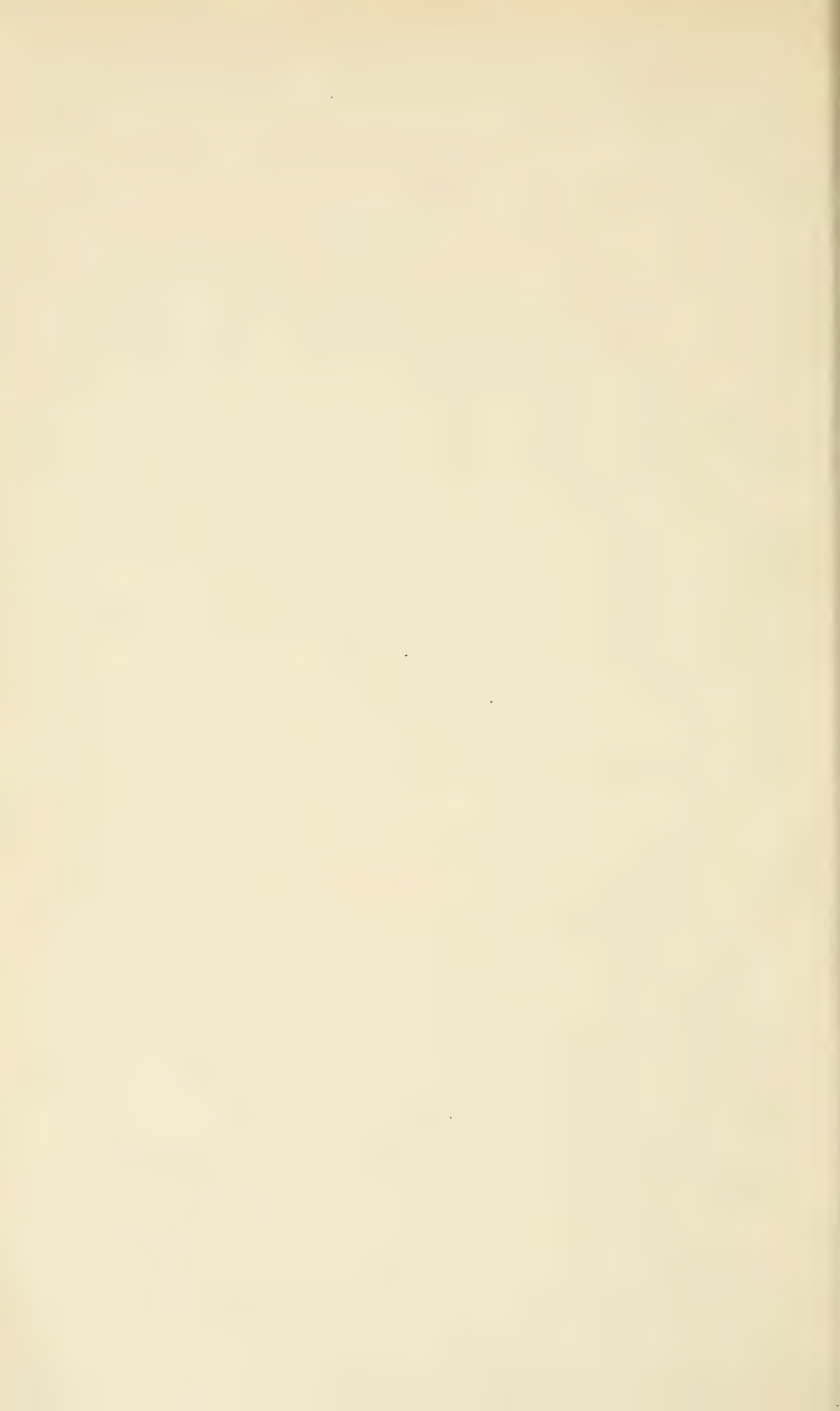


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MYOLOGY

GENERAL MYOLOGY

IN the widest acceptation of the term, Myology includes the description of the whole of the tissue which possesses the property of contractility. The essential elements of the tissue are the muscular fibres which, grouped into bundles, determine the direction of contraction, and consequently the movements of the body or its parts.

The greater part of the muscular tissue of the body is attached to the skeleton, and takes part in the formation of the body wall and the extremities. Another part smaller in amount occurs in the walls of the viscera and blood vessels, and in the sense organs and skin. This division corresponds in a general way to certain structural differences and functional peculiarities, so that the muscles of the former group are termed *skeletal*, *striped* or *voluntary*, being under control of the will, and those of the latter *visceral*, *smooth* or *involuntary*.

While this distinction prevails in a general way it is not absolute. The smooth or non-striped muscle represents a less advanced stage of the striped variety. Certain portions of the proper visceral musculature, not under the control of the will, are striped. It is probable that the structural differences are ultimately to be explained on functional rather than on strictly morphological grounds.

In this volume the voluntary or skeletal muscles alone will be described. The visceral musculature, and the intrinsic muscles of the tongue and of the ear, are best dealt with under the head of the organs of which they form a part. With the muscles the fasciæ which invest and support them will also be the subject of description.

The voluntary muscles are for the most part attached to the bones or other hard parts. Moving these in different directions by their contractions, they bring about the displacements at the joints which have been studied in the section on Arthrology (Vol. IV., Part I.). The actions of the muscles are of much importance from a practical point of view, especially in Orthopædic Surgery. They will therefore be fully considered, and an attempt will be made, as far as limits permit, to formulate the mechanical principles underlying the operations of the muscles.

The Structure of a Muscle.—Each muscle constitutes a separate organ. It is composed of contractile muscle fibres associated with accessory fibrous tissue parts which invest and serve to fix the contractile substance. The muscular fibres are grouped together in bundles or fasciculi, and these again are united together by a loose connective tissue, which is known as the *perimysium*. The whole muscle, built up of these secondary fasciculi thus connected together and provided with common terminal attachments, is enclosed in a denser external

sheath, the *epimysium*.¹ Individual muscles vary in the amount and arrangement of the connective tissue within their substance, as well as in the arrangement and direction of the fasciculi. Roux states that the connexions of the perimysial sheaths of the neighbouring fasciculi occur in a definite manner, and believes that they serve to regulate the extent of contraction of the individual fasciculi. Throughout the connective tissue within the muscle elastic fibres are distributed.

The texture of muscles is determined by the size of the component fasciculi, so that the muscle appears coarse when the fasciculi are of large size, and of finer grain when they are delicate. The fasciculi also vary in length, and this quite irrespective of the length of the whole muscle; their extent depends mainly on the interrelation of the contractile and tendinous parts of the muscle.

At each extremity the contractile substance is attached to the bones or other hard parts by fibrous tissue formations. The general structure of these resembles that of muscle, in that the component fibres are arranged in bundles enclosed by looser tissue comparable to the perimysium. Sometimes the fibrous structures are so slightly developed that the muscle tissue appears to be directly connected with the parts to which it is attached. In other cases a rounded or flattened band called the *tendon* is formed, and this often extends a considerable length on the surface of the muscle or within its substance. Again the attachment may be effected by a broad thin expansion, or *aponeurosis*.²

The attachment of a muscle by a tendon enables the force exerted in contraction to be concentrated on a limited area. It also permits the muscles to act from a considerable distance, and in consequence the more bulky, fleshy belly to be situated in the most convenient situation.

All these tendinous attaching structures are probably to be regarded as modified mesenchymatous skeletal parts, the form of which is determined by the extent and direction of the attached muscle fibres. In some cases it is believed that tendons or aponeuroses may represent regressive muscular tissue present at an earlier stage of development, or existing in an earlier phase of phylogeny and retained in lower vertebrates. It is very doubtful whether muscular tissue ever regresses in this way, but it is tolerably certain that the tendinous and connective tissue elements of a muscle may persist after the disappearance of the fleshy fibres.

Blood vessels are distributed very freely in the substance of a muscle, in number commensurate with its high degree of functional activity. The larger branches perforate the muscle along the fibrous septa in the direction of the muscle fibres. They form a characteristic rectangular capillary plexus. Lymphatic vessels are abundant in the perimysium and in the fibrous tissue of the tendons, which are only sparsely provided with blood vessels. The lymphatics follow for the most part the course of the blood vessels. The vascular system of each muscle forms in itself an "end circulation," there being practically no anastomosis with the vessels of the surrounding connective tissue (*Spalteholz*).

Nerves ramify in each muscle. They transmit the stimuli to produce contraction and to preserve the muscle tonus, and they convey to the central nervous system the afferent impressions concerned in the maintenance of the tonus.

The nervous supply to a muscle is rarely effected by a single nerve trunk. The more usual arrangement is a division of the trunk into a number of branches, often interconnected, which enter with the main blood vessels along a linear *neuro-vascular hilum* (*Frohse*). The length of the nerve is always sufficient to prevent it from being stretched during the displacements occasioned by the

¹ For the microscopic characters of muscle fibres and details of the other parts of the muscles, see Vol. II., Part I.

² For definition of this term, see p. 16.

contraction of the muscle. In a few cases a state of tension of the nerve may be produced by passively forcing the parts into certain positions. The nerve entrance is generally placed on the deep or skeletal surface of the muscle; sometimes it is at the margin. Schwalbe and Roux state that the nerve enters the geometric centre of each muscle. It is doubtful whether this is more than approximately true. Chaignon describes the entrance point, in the case of the limb muscles, as never occurring in the proximal fourth or in the distal half. Once the nerve twigs have entered the muscle, they unite with one another, or with the twigs of other nerves, if the supply be multiple, into a series of complex plexuses. The type of plexus varies, and is said to be specific for each muscle (Frohse). It includes both motor and afferent fibres, and distributes twigs to the tendons as well as to the contractile substance.

THE CLASSIFICATION OF MUSCLES ACCORDING TO THEIR FORM AND THE ARRANGEMENT OF THEIR COMPONENT ELEMENTS

The great majority of voluntary muscles are attached at either end to portions of the skeleton, passing over one or more joints at which they may effect movement by their contraction. A few muscles are attached in part, or in entirety, to fascia or to skin, *e.g.* the muscles of facial expression; others have one or both ends fixed to the tendons of other muscles, *e.g.* the quadratus plantæ and the lumbricals; others, again, pass between skeletal parts and special organs, *e.g.* the muscles of the eyeball.

In the description of the muscles it is customary to describe the attachments of their opposite ends under the names of *origin* and *insertion*, the first term being applied to the more fixed, or in the case of the limbs the more proximal extremity, and the second to the more movable or distal attachment: but it is often difficult to decide the correct use of these terms, and in the majority of instances it is necessary to consider the action of a muscle in relation to the movement it may effect at both of its attachments. The fleshy central part is usually referred to as the *belly* of the muscle.

The muscles vary much in their individual forms. Some are broad and thin sheets, others are more or less elongated straps, and others are cylindrical or fusiform masses of varying thickness: hence some of the various names applied to them, such as *latissimus*, *quadratus*, *teres*, etc. Not infrequently two or more distinct muscular parts fuse together in a common insertion and constitute the *bicipital*, *tricipital*, or *quadricipital* forms. In other instances muscles, originating as single masses, are divided at their distal ends into two or more muscular or tendinous slips. A division of a muscle into two parts by an intermediate tendon gives the form called *digastric*, or *biventral*, and there are some muscles in which a greater number of parts are thus separated by what are called *inscriptions tendineæ*. Round the orifices of the body, *orbicular* or *sphincter* muscles occur; they consist of fibres with a crescentic course in either lip of the opening.

The fact that a muscle is multicipital is not necessarily an expression of the morphological unity of the whole, but is rather an indication of the more or less complete correspondence in function of its parts. The bicipital type may result from the partial fusion of two originally distinct muscles which had a common insertion; or it may indicate a division of an originally complete muscle in consequence of a degeneration of an intermediate part. The digastric form may be the result of an end-to-end union of the tendons of two primarily distinct muscles. In other cases the central tendon may represent a persistent intermyotomic septum, or again it may be produced by a secondary attachment of the muscle in consequence of its being bound down to a neighbouring skeletal part. The type to which a particular muscle belongs may as a rule be determined from the nerve supply (see below).

The muscles may also be described and classified with advantage for the determination of their mode of action, according to the arrangement of their component fibres. In this connexion the following general principles ought to be kept in view: (1) That the force exerted by any muscle during its contraction is in proportion to the *number* of muscle fibres composing the muscle. (2) That the extent of the resulting motion, in so far as it depends on the shortening of muscle, is in proportion to the *length* of the muscle fibres. (3) That the direction of the force of a contracting muscle, that is of the *muscle resultant*, is in the line of the axis of the whole muscle if it run straight between its opposite points of attachment, but, if the muscle or its tendon be bent in its course, is in the line of the axis of the portion attached to the moving part.

The following types of muscles indicate the main varieties of fascicular arrangement:—

1. Muscle Fibres Forming Plane Surfaces.

- A. The muscle fibres are parallel and rectilinear.
 - 1. Quadrilateral muscles.
 - 2. Fusiform muscles.
 - 3. Rhomboidal muscles—Unipenniform
Bipenniform.
Multipenniform.
- B. The muscle fibres are parallel and curvilinear.
 - 1. Sphincter muscles.
- C. The muscle fibres are rectilinear but not parallel.
 - 1. Triangular muscles.

2. Muscle Fibres Forming Curved Surfaces.

- A. The muscle fibres are curvilinear.
 - 1. Spheroidal muscles.
 - 2. Ellipsoidal muscles.
- B. The muscle fibres are rectilinear.
 - 1. Skew muscles.

General Muscle Mechanics.—The following are the more elementary principles of general muscle mechanics. The amount of work (W) available from the contraction of a muscle depends on two factors: (1) the *absolute force of contraction* (F), and (2) the *length of shortening* (dL) of the muscle. This is expressed in the formula $W = F \times dL$.

The amount of shortening which a muscle may undergo depends directly on the length of its fibres. There are many difficulties, however, in the way of estimating the *natural length* of the fibres of a muscle, since their length varies (1) according to the position of the joint or joints operated upon; (2) according to whether it be measured with the attachments intact or divided; (3) according to the presence or absence of the opposing group of muscles; (4) according to whether it be in a state of response to nerve stimuli or not. In practice the *natural length* of the muscle fibre is measured with the muscle intact, with the joint operated upon in its mid-position, with the antagonist muscle in action and in the absence of voluntary nerve stimuli. The amount of shortening which this length of muscle fibre may undergo varies according to the factors already mentioned, but the length of the contracted muscle fibre is taken as the length of the muscle in its maximum of voluntary contraction, the related joint being in the extreme position of the habitual movement produced actively by the muscle, with the antagonist muscles in operation. Now if L be the natural length and dL the measure of the shortening, the length of the contracted fibre will be $L - dL$, and according to the Weber-Fick law this is equal to one-half of the natural length L . In other words, a muscle fibre can be voluntarily contracted to one-half of its natural length. The extremities of certain muscles may, however, be approximated more than is possible by voluntary contraction. These muscles are then said to be *actively insufficient*. In the position when they are thus actively insufficient they are flaccid and slackened between their attachments. In respect, however, that these positions are never habitually nor voluntarily

assumed, they form no exception to the general law that the length (as well as the thickness) of muscle fibre is in direct relation with its function (Roux).

The absolute force of contraction of a muscle depends directly on the number of its fibres, and is obtained from the formula $F = nX$, X being the coefficient of muscle fibre contraction.

The coefficient of muscle fibre contraction depends on the thickness of the muscle fibre. This varies in every muscle, but it is not practicable to estimate the number and thickness of the fibres in each individual muscle. Accordingly in practice the area of the physiological transverse section is substituted. If this be taken as Q , then the formula becomes $F = QX$.

The area of the transverse section (Q) may be obtained by direct measurement of the cut surface. In quadrilateral and fusiform muscles a section through the thickest part of the belly at right angles to its long axis is measured (fig. 1). This is the anatomical transverse section, but in other muscles this does not suffice; a section at right angles to all the fibres, *i.e.* the physiological transverse section, is required. The area may also be obtained by indirect means from the formula devised by Weber, viz. :—

$$Q = \frac{P \text{ (weight of the muscle)}}{L \text{ (mean length of muscle fibres)} \times S \text{ (specific gravity of muscle)}}$$

The coefficient of muscle contraction (or the unit of muscle force) (X) has been estimated by direct experiment. According to Johnston, it has the mean value of 10 kgm. per sq. cm. of physiological transverse section, the joint acted upon being in its mid-position. Haughton gives the figure as 7.2 kgm., Henke as 8.7 kgm. per sq. cm. If the coefficient be taken as 10, the formula given above now becomes $F = Q \times 10$, and the maximum available work of a muscle (W), when the maximum length of contraction of its fibres (dL) is one-half the natural length (L), may be expressed in the formula—

$$W = Q \times 10 \times \frac{L}{2}$$

The application of these principles to the different types of fascicular arrangement allows valuable deductions to be made regarding the uses of the different types of muscles.

I. The Muscle Fibres Form Plane Surfaces

(A) The muscle fibres are parallel and rectilinear.

(1) **Quadrilateral Muscles.**—In this variety of muscle the fasciculi are parallel, and run in a straight line from origin to insertion (fig. 1). The fasciculi act as parallel forces, and the muscle resultant (F) is a force equal to the sum of the forces of the fasciculi, and acts at right angles to the insertion in the line joining the centres of gravity of the origin and insertion. The whole available work of such a muscle will be employed in approximating its attachments. The cross section remains constant over the whole length of the muscle, and coincides with the anatomical section. The thyreo-hyoid muscle may be cited as a typical example, but the strap-shaped muscles, shorter like the sterno-hyoid or longer like the sartorius, come into the same category.

(2) **Fusiform Muscles.**—There are few examples of pure quadrilateral muscles in the body, but fusiform muscles (fig. 2) are more frequent. A fusiform muscle tapers at both ends, but the fasciculi depart very little from a parallel course, and its tendons of attachment lie in the direction of the fibres. These muscles resemble quadrilateral muscles in the mechanism of their action. The resultant of contraction falls in the axis of the tendon of insertion, and is equal to the sum of all the fibre forces, while the amount of displacement is equal to the whole shortening of contraction. The area of transverse section remains almost uniform throughout the fleshy part of the muscle.

(3) **Rhomboidal Muscles.**—These muscles consist of fasciculi which are parallel to one another, but pass with a greater or less degree of obliquity from origin to insertion. The semi-membranosus is a typical rhomboidal muscle, but there are many others. Most of the muscles arising from the bones of the forearm are of this variety. The pull of such a muscle when it contracts may be resolved into two components, a horizontal and a vertical (fig. 3). The horizontal component tends to draw the origin and insertion together, while the vertical, or component of translation, acting in a line parallel to that of the attachments, tends to move them past one another. Muscles of this kind are called *unipenniform*, and it becomes of some importance to estimate the relative amounts of the components of the pull in order to determine the distribution of the available muscle work. These are best expressed in terms of the angle of inclination of the muscle resultant. Thus as shown in fig. 3, $X = F \cos a$; in other words, the smaller the angle between the muscle fasciculi and the tendon of insertion, the greater will be the proportion of the vertical component or component of translation in the pull, which affects the displacement of the insertion.

A further modification of this arrangement of muscle fasciculi and tendon occurs in what are termed *bipenniform* muscles (fig. 4). These consist of two series of rhomboidal muscles attached,

usually with equal angles of inclination, to the opposite sides of a central tendon. In this case the component of translation will be double that of the unipenniform muscle, *i.e.* $X = 2F \cos a$, while the approximation components of the opposite fasciculi will equalise and neutralise each other ($y \sin a = y' \sin a$). Other muscles are found to contain a number of such central tendons, and the

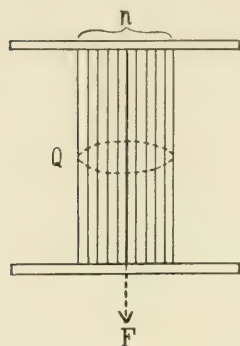


FIG. 1.—QUADRILATERAL MUSCLE.

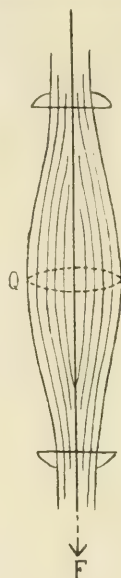


FIG. 2.—FUSIFORM MUSCLE.

In both figures: n , number of fibres; f , force of contraction of each fibre; Q , area of transverse section; F , muscle resultant. $F = nf = Q \times 10$.

muscle fasciculi being attached to them in penniform fashion, the entire mass constitutes a *multi-penniform* muscle. The deltoid muscle is made up of seven distinct penniform muscles.

The work done by the bipenniform type may be estimated as follows (fig. 5): Let AM and BM represent the resultants of the two parts of a bipenniform muscle, and let L be the length of each.

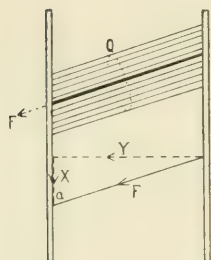


FIG. 3.—RHOMBOIDAL MUSCLE.

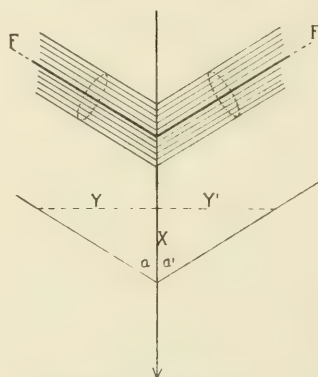


FIG. 4.—BIPENNIFORM MUSCLE.

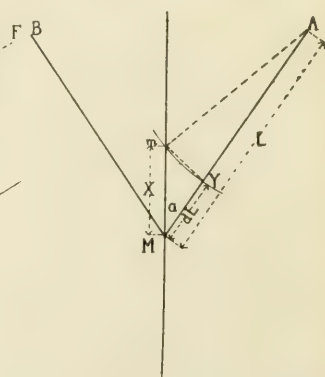


FIG. 5.—DIAGRAM SHOWING WORK DONE BY A MUSCLE OF BIPENNIFORM MUSCLE.

During contraction they are each shortened by the length dL , and M is moved to draw MY perpendicular to AM , then $MY = dL$, and the distance $Mm = dL \sec a$. The resultant force ($x = 2F \cos a$) in the direction Mx multiplied by this distance is the work done by the whole muscle.

$$\text{Work done} = 2F \cos a \, dL \sec a$$

$$= 2FdL, \text{ which represents the total available work of the muscle}$$

if arranged in a quadrilateral manner; so that there is no loss of work due to the bipenniform arrangement.

The formula $L \sec \alpha$ would represent the length of the quadrilateral muscle, whose contraction would equal in length that of the whole bipenniform muscle: *e.g.* (from Haughton) if the whole bipenniform muscle length is 6 in. and the fibres are 1.84 in., and make an angle of 55° with the central tendon, the total amount of its contraction could be produced by a quadrilateral muscle of length

$$L = 1.84 \text{ in.} \times \sec 55^\circ \\ = 2.85 \text{ in.}$$

The intention of the penniform arrangement, therefore, is to produce a powerful pull through a small space, while the quadrilateral form will produce a greater extent of displacement, but will act with less force.

(B) **The muscle fibres are parallel and curvilinear.**

(1) **Sphincter Muscles.**—In a sphincter muscle each fibre forms a curve, not often in itself closed, circular or elliptical in shape, and the collection of such fibres, parallel and on the same plane, compose the entire muscle. A sphincter muscle, therefore, is placed round an orifice

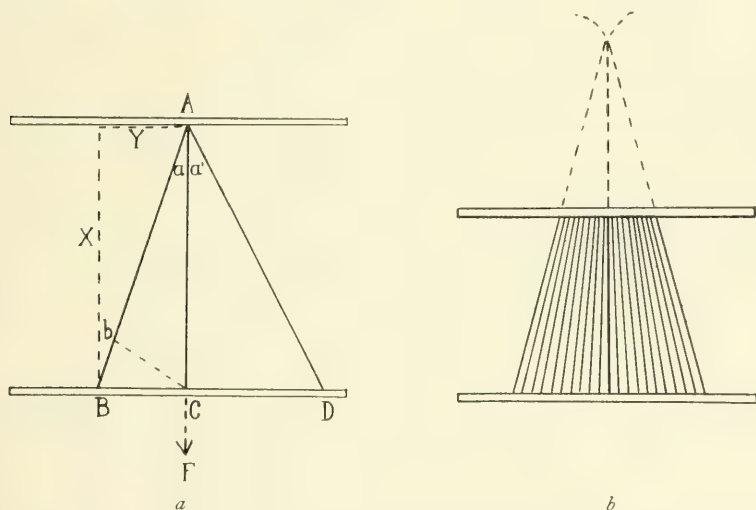


FIG. 6.—TRIANGULAR MUSCLES.

In *a*, the muscle fibres converge to a point; in *b*, the converging fibres are interrupted by the insertion before they reach the point of convergence.

$$F = 2f \frac{X}{Y} \cdot BC : CD :: AB : AD.$$

which is closed by the contraction of the fibres. The contraction of a sphincter muscle can only produce tangentially acting forces, to equilibrate which a set of perpendicular forces must be generated by a distinct set of radiating fibres. Two sets of muscles, antagonistic in action to each other, will therefore be found round each opening. The sphincter muscle of the eye (*orbicularis palpebrarum*) may be taken as an example. The orbital portion forms nearly spherical rings which spread some distance upwards on the forehead and downwards on the cheek. There they are blended with the antagonistic radiating fibres of the frontalis and malar muscles respectively. The palpebral portion, more elliptical in curvature, is blended in the upper lid with the *levator palpebræ superioris*, which forms the radiating antagonist. The orbicular muscle of the mouth is placed in a similar, though more complex, relation to the radiating muscles of the lips.

There are other sphincters, however, which surround apertures not opened by muscular agency. Such muscles (*e.g.* *sphincter ani externus*), on contraction, close the apertures which have been dilated by some non-muscular force (*e.g.* the passage of the bowel content), and are not balanced by antagonistic fibres. Radiating fibres are not therefore found in relation to them.

(C) **The muscle fibres are rectilinear but not parallel.**

(1) **Triangular Muscles.**—These muscles are such as arise from a wide origin and converge to a narrow insertion, *e.g.* the *adductor pollicis* or the *trapezius*, or conversely pass from a pointed origin to a linear insertion, *e.g.* the *adductor longus*, there being differences in different muscles in the size of the angle included between the marginal fibres (fig. 6). When such a muscle

contracts as a whole, the resultant force is directed in the bisector of the apical angle, but the amount of displacement it may produce, and therefore the amount of work done, is diminished in direct proportion to the increase of the obliquity of the fibres to the muscle axis. This loss, however, is compensated, in some degree, by the capacity possessed by these muscles to contract in parts and so to be employable in a variety of movements. On this account triangular muscles not uncommonly exhibit radial segmentation. It must be understood, however, that even though a muscle has its fibres running in different, or even in opposite directions, the different parts may be associated together in the production of a common movement. The trapezius, for example, contracting as a whole, elevates the shoulder (*cf. post*), though its upper and lower fibres have opposite directions.

II. The Muscle Fibres Form Curved Surfaces

In the types of muscles described above, the constituent fibres have been considered to lie on plane surfaces, though this condition is rarely fulfilled with mathematical exactness. There are other muscular sheets, however, whose surfaces are definitely curved, and these may be termed in short the curved muscles. These curved muscle surfaces may be considered in two classes: (1) those whose curvatures at any point are in the same direction, *i.e.* are spheroidal surfaces; the effect of the contraction of such muscles is to compress the contents enclosed within them; (2) those whose curvatures at any point have opposite directions; they have been termed in muscle mechanics skew surfaces.

(A) **Fibres are curvilinear.**—The *spheroidal muscles* may lie on the wall of a sphere. On contraction the tangential stress in this case will be the same in every azimuth at each point. If the surface curvature is *ellipsoidal*, the perpendicular stress remains constant, but the tangential stress will be different in different azimuths. The greatest and least tensions will be at the extremities of the major and minor axes, and will be proportional to the squares of those axes. The muscles of the abdominal wall, and also the diaphragm, belong to the latter class, and it becomes of some importance to estimate the pressure induced in the abdominal cavity by their contraction, and available for the expulsion of urine, faeces, or at child-birth. In regard to the abdominal muscles this may be accomplished (Haughton) with the aid of Lagrange's theorem—

$$P = T \times \left(\frac{1}{\rho'} + \frac{1}{\rho''} \right),$$

where ρ' and ρ'' are the radii of the principal curvatures of the abdominal surfaces; T is the tangentially acting tensile stress produced by the contraction of a linear strip 1 in. broad of the muscles; and P is the pressure resulting from all the forces in action perpendicular to the surface and acting on an area of 1 sq. in. (T may be obtained from a multiplication of the average total thickness of all the muscles of the abdominal wall and the coefficient of muscular contraction.) The average total thickness of the muscular wall of the abdomen is 1.3 in., and the coefficient of muscular contraction 102.5 lbs. (p. 5); therefore $T = 1.3 \times 102.5 = 133.67$; ρ' and ρ'' are 11.36 and 6.34 in. respectively. Then $P = 133.67 \times (1/11.36 + 1/6.34) = 32.9$ lbs. per sq. in. available as an expulsive force on each square inch of the abdominal wall. Acting on a pelvic canal of $4\frac{1}{2}$ in. diameter, this would represent a force of 523 lbs. (about one-quarter of a ton).

(B) The **skew surface muscles** are such as consist (in their simplest form) of straight muscle fibres which pass between corresponding points on attachments which do not lie in the same plane, the distance between these points being of equal anharmonic ratios. This form of skew muscle may be regarded as a quadrilateral muscle whose origin and insertion have been twisted into different planes to constitute a *skew quadrilateral*. Its surface curvature is hyperboloid, and it is an open surface and cannot be made to enclose a space. The effect of the contraction of all its fibres results in an effort made by the surface to destroy its own curvature and to revert to the condition of a plane surface, with origin and insertion in that plane. This would be accompanied by a twisting motion of the entire sheet. These muscles, therefore, are found passing from an origin which is fixed to an insertion which is subject to a variety of conditions in its motion; the most usual of these is that it is compelled to turn round some fixed ball and socket joint. The adductor magnus is an example of a skew-quadrilateral muscle.

THE ACTION OF MUSCLES

The contraction of a fleshy belly of a muscle which is attached to bones or other hard parts, and extends over one or more joints, may result (1) in the displacement in space of one or both of its attachments, it is an *effector of movement*,

(2) in the fixation of its attachments in the position of displacement, it is a *checker of movement*; (3) in the retention in contact of the surfaces of the joint or joints over which it extends, it acts as a *joint approximation force*.

I. The Muscles as Effectors of Movement

The gross mechanism of an individual muscle may be inferred from its attachments, and the relation which the *muscle resultant*, as determined on the principles laid down above, bears to these attachments. But so long as we deal only with individual muscles, so long as we think only in terms of individual action, we get small insight into the principles of the muscular system. As a matter of fact, no one muscle acts alone in the actual production of any body movement.¹

A number of muscles are always associated together in co-ordinated action. In the cerebral cortex it is the movements that are pictured, not individual muscle actions. The muscles which act together are referred to as a *muscle group*. Further, in the ordinary performance of any body movement no one group ordinarily acts alone, but different muscle groups become concerned in the movement at one and the same time, and for different purposive activities (*v. post*).

It is not of much value, therefore, to discuss the action of isolated units, or to compile tables of the action of individual muscles under the headings of Extensors, Flexors, Rotators, etc. It is much more important to know in what movements each muscle may take part, and what share it takes in each movement. By analysing their action it is found that most muscles, as pure effectors of movement, are capable of producing a variety of displacements of the parts to which they are attached. It is found, even, that different parts of a single muscle may fall into different groups producing different movements, or may contract at different times in the completion of one movement. As a rule one of the actions is considered as the primary action, and the others secondary.

TABLE I.—ACTIONS OF THE MUSCLES OF THE HIP-JOINT

	Flexion.	Extension.	Abduction.	Adduction.	Med. Rot.	Lat. Rot.
Glut. max - - - -	...	+(1)	...	+(2)	...	+(1)
„ med. - - - -	...	+(6)	+(1)	...	+(1)	...
„ min. - - - -	+(9)	...	+(2)	...	+(2)	...
Pyriformis - - - -	...	+(7)	+(3)	...	...	+(4)
Obturator inter. - - -	...	+(8)	...	} + (11) {	...	+(3)
Gemelli - - - -	...	...	...		...	...
Quadratus fem. - - -	+(12)	...	...	+(5)	...	+(2)
Adductor mag. - - -	+(10)	+(2)	...	+(1)	+(4)	+(7)
„ longus - - - -	+(3)	...	...	+(4)	+(6)	...
„ brevis - - - -	+(4)	...	...	+(3)	...	+(6)
Gracilis - - - -	+(11)	...	...	...	...	+(11)
Pectineus - - - -	+(7)	...	...	+(8)	+(5)	...
Rectus fem. - - - -	+(2)	...	+(4)	...	...	+(5)
Psoas and iliacus - - -	+(1)	...	...	...	+(3)	...
Tens. fasc. fem. - - -	+(6)	...	+(5)	...	...	+(12)
Semitendinosus - - -	...	+(4)	...	+(10)	+(7)	...
Semimembranosus - - -	...	+(5)	...	+(12)	+(8)	...
Biceps - - - -	...	+(3)	...	+(9)	...	+(8)
Obtur. exter. - - - -	+(5)	...	...	+(6)	...	+(10)
Sartorius - - - -	+(8)	...	+(6)	+(7)	...	+(9)

Compiled from various sources. The popliteus is not reckoned as a femoral muscle.
The numbers indicate the relative power-values of the different muscles.

¹ The muscles of the middle ear are probably exceptions to this rule.

The *secondary* are either constant accompaniments of the primary action or are occasional and operative only in some particular position.

When movements are analysed it may be ascertained, by observing the muscles in contraction, that they are the result of the action of a combination of muscles. It is found in some instances that a muscle may contract in the movement of a part to which it is not attached; for example, the flexor carpi ulnaris contracts in abduction of the thumb. Again, a muscle may not contract in a movement in which its origin and insertion are approximated; for example, the flexors of the wrist do not contract when the wrist is flexed by the flexors of the fingers.

Table I. shows, by way of example, the analysis of the actions of the muscles producing the primary movements of the hip-joint. It demonstrates the common displacements which would result from the contraction of any unit or group. It shows that we need not ordinarily be concerned in the actions of units. A number of muscles may produce each primary movement, and it will be observed from the table that the full action of the sum of the units effecting one movement would be accompanied by accessory movements. Thus extension would be accompanied by abduction and adduction, as well as by medial and lateral rotation of the limb, or the movements of the trunk which would determine those relative displacements. It is obvious, therefore, that compound displacements though they may be, the habitual movements are not produced by the simple association of all the units capable of effecting them.

The manner of the arrangement in their several groups of the muscles which take part in any movement has been the subject of inquiry from the time of Galen to the present day; and it is still a matter of controversy. There are two points, however, which should be kept constantly in mind in seeking to define the association in groups of the muscles which take part in any movement: (1) the complexity of the movement permitted at the joint at which the movement is taking place; at a simple hinged joint, for example, the muscles will be in only two opposing groups, but at a joint which permits of movement in more than one plane, there will be added other groups to define the plane of a simple movement; (2) the number of joints at which a muscle may produce movement. If a muscle be capable of effecting movement at more joints than one, and the movement at one only be required, then a further group of muscles must be brought into action to fix the joints which are not to be moved.

It is on these bases that the following classification of the groups of muscles is made¹:—

- (1) *Prime movers.* (2) *Synergists.* (3) *Fixation muscles.* (4) *Antagonists.*

Many muscles may function, at different times, in all of these groups. The flexor carpi ulnaris, for example, is a prime mover in certain flexions of the wrist, an antagonist in certain extensions of the wrist, a fixation muscle in certain extensions of the fingers, but is a synergist when it contracts in abduction of the thumb. It should be noted, further, that when a muscle belongs to different groups, it will have different associates in each. Its antagonist in one group may even be its associate in another. The flexor carpi ulnaris, for example, is opposed by the extensor carpi ulnaris in certain flexions of the wrist, but in adduction of the wrist the two muscles are associated together as prime movers. It is of clinical importance to note, in this connexion, that a muscle which takes part in two different movements may be paralysed for one but not for the other, for instance in paraplegia. Numerous cases of this have now been published; for example, the biceps may lose its power as a supinator of the forearm, but retain its power as a flexor. It has also been pointed out by Hughlings Jackson that a muscle may be paralysed for all unilateral movements, but still be able to act in bilateral movement.² The trapezius furnishes a fairly frequent example of this phenomenon in cases of paraplegia.

¹ The terminology of these groups is by no means fixed.

² This has been said to occur only in lesions above the basal ganglia.

The *prime movers* are the muscles which directly effect the required movement. When a prime mover by passing over more than one joint can effect more than one movement, its action is associated with that of other muscles brought into operation to prevent the movements which are not required. These muscles are termed the *synergists* (pseudo-antagonists, Hering). Hering has shown (in the monkey) that on stimulation of the cerebral cortex the synergists are thrown into action simultaneously with the prime movers. They must be regarded, therefore, as essential associates of the prime movers, and they cannot be voluntarily eliminated in the movement. The *fixation muscles* are those which act on the joints which intervene between that at which the movement is taking place, and the fixed base from which it is performed. For instance, if a grasping movement be made powerfully with the hand, not only do the muscles directly concerned in flexion of the fingers and thumb contract, but also the extensors of the wrist, the flexors and extensors of the elbow, and in very strong grasping movements even the muscles of the shoulder. The elbow and shoulder muscles are in this case acting as fixation muscles, and the grasping movement is made from a *fixed point* (Hunter) on the arm. The determination of the fixed points for any combination of movements will depend on the position of the body and the parts of the body which form the fixed bases of the movements. The muscles which fix the points or bases of movements are the fixation muscles. The *antagonist muscles* in any movement are those which effect the opposite or reverse movement at the same joint. The part played by the antagonists is a much disputed question and is, in the main, physiological rather than anatomical. The point at issue is whether the antagonists are actually passive (Galen) or whether they actively co-operate to moderate or regulate the movement (Winslow; probably this was also Hunter's view). Winslow adds, however, that the want of the action of the antagonists may be supplied by the weight of the part, or the resistance of some other body. Duchenne is more emphatic for this view than Winslow, and omits the qualification. More recent works, however (Brucke, Beaunis, Demeny, Beevor), would appear to confirm Winslow's statement. The conclusions arrived at may be summed up as follows: In movements where there is no resistance, the antagonists act as moderators of the rate of movement, but if resistance is made against the movement the antagonists relax. Experiments by Sherrington and Hering (on the monkey) would seem to challenge this view, for it appears to be demonstrated that not only are the antagonists to a movement relaxed, but actually inhibited, and that the inhibition starts from the same part of the cortex as the excitation of the prime movers. The antagonists may act to control a movement produced by gravity (p. 13).

Certain of the more mechanical aspects of muscle action pertain to an anatomical description, because they have some bearing on the actual morphological arrangements, and also on the group actions which will be described later for each of the joints. Further, it should be mentioned that they cannot be discounted in the operative procedure of the surgeon.

When a skeletal muscle has one or both of its attachments to soft parts, as in the case of the facial muscles, its contraction effects a direct approximation of its attachments in the line of the muscle fasciculi. A modification of this simple result has already been noted in the case of the sphincter muscles. When the muscles are attached to bones or other hard parts they may be considered as the force components in a lever mechanism.¹ They supply the power, or better, the *effort*, while the *resistance* is represented by the weight of the part to be moved and the pull of the antagonistic muscles. The result depends, of course, on the position of the *fulcrum* relative to effort and resistance, but also on the angle at which the effort is applied to the lever arm. The classical example of a lever mechanism in the body is the lifting of a weight in the palm of the hand by bending the arm at the elbow-joint. The power or effort effecting the movement (biceps and brachialis muscles) is applied between the resistance (here the weight) and the fulcrum at the elbow-joint. It will be noted that in this mechanism, as is most frequently the case in the animal body, the point of application of the force is much nearer the fulcrum than the weight. It follows, therefore, that a slow and small contraction of the muscle will produce a rapid and extensive motion of the weight; and further, the contraction is associated with but little change in the disposition of its fibres, and with little effect on the surrounding structures. The length of the muscle fasciculus required is therefore not commensurate with the rate and extent of motion. On the other hand, the consequence of such an arrangement is that the muscle must exert a force many times greater than the resistance to be overcome, and thus necessitates a relative increase in the cross section, that is, in the number of muscle fibres. The forearm also provides in the movement of extension against a force applied to the hand, an example of a lever system in which the fulcrum,

¹ Exception should be made of the muscles acting on the hyoid bone and certain of these moving the scapula, whose action is similar to those acting on soft parts.

again placed at the elbow-joint, lies between the point of application of the effort and the resistance. The third case, represented in the second class of the classical orders of levers and in which the resistance falls between the effort and the fulcrum, seems at first sight to be realised at the ankle-joint when the body is raised on the balls of the toes by the lifting of the heel from the ground, the fulcrum being at the balls of the toes and the weight transmitted through the tibia. It is more probable, however, that in this mechanism the fulcrum is placed at the ankle-joint, as the effort arm is shorter than the weight arm, and the power is greater than the weight. The result will vary, however, with the position of the joint, and it must be noted that in deducing the action of muscles in lever systems the lengths of the lever arms are not simply the distances measured on the bones between the fulcrum, effort, and resistance, but are represented by lines drawn from the fulcrum perpendicular to the planes in which the resistance and effort are acting (fig. 7). As all bones move on a centre, or axis of motion, and the muscle attachments more or less on a circumference, the muscles while changing the position of the bones must at the same time be changing the direction of their action, and so varying the details of their lever mechanism. Thus it is that to complete most of the ordinary movements, the *sphere of action* of any one individual muscle is usually insufficient, but is continuous with, and leads into, the spheres of action of the other muscles associated with it in the movement, and so there is constituted a *group sphere of action* co-terminous with the complete movement.

The facts stated above lead directly to the inquiry as to the incidence of the maximum activity of a muscle. This may be stated as follows: A muscle exerts its maximum effect in moving a bone round a joint when the direction of the resultant of all its fibres (the plane of its action) is perpendicular to the line joining its point of action and the centre of motion of its joint (the lever arm).

For example, in fig. 8, let S be the centre of the shoulder-joint, SN the humerus, and Q the centre of the insertion of the latissimus dorsi AQB, whose resultant is QX. Place the arm in such a position SN' that the angle SQ'X is a right angle, and in this position the latissimus dorsi effects its maximum effort in moving the arm round the shoulder-joint; the position (43° of depression, Haughton) naturally assumed in any form of back-hand stroke.

The mechanical association of the members of muscle groups may be shown on the above finding, as well as the separate action of each muscle in the series. For example (fig. 9), with the arm in the position SQ'N' and the angle SQ'X a right angle, the resultant of the teres major MQP is so placed that the angle SPM is almost a right angle. That is, that the teres major and the

latissimus dorsi are so arranged as to produce their maximum effect on the joint at almost the same time, but the teres major will act most powerfully slightly later than the latissimus. Further, if A be the centre of the origin of the long head of the triceps and B its insertion on the olecranon, the angle SAB' is also almost a right angle; that is, the long head of the triceps is associated with the latissimus and the teres muscles to effect movement at the shoulder-joint at the same time and with its maximum power.¹

The fact that the triceps muscle is arranged to act in this manner on the shoulder-joint, while the elbow being a ginglymus (fig. 9), it may be effecting its maximum action at the elbow-joint, demonstrates the definite association of joints in action. In other words, between the separate articulations of a part of the body, say of a limb, there is such an association of movements, that movement at one of the joints is, normally, associated with, or productive of, definite and peculiar movements of the others. This association of joint movement is more often the result of the *ligamentous action* of muscles (*v. post*), but in certain cases is induced by their active contraction, and allows a mechanical analogy to be established between muscle groups. The hamstring muscles of the lower limb, for example, act on the hip-joint while the gastrocnemius group are producing their maximum effect at the ankle. The gastrocnemius bears to the hamstrings the same relation, mechanically, that the triceps does to the latissimus and teres major. A further result is, that in the movements of a peripheral joint of a limb the more proximal joints require to be fixed, if any resistance is to be overcome.

In a more general sense, however, it may be said that each individual muscle seeks to set the

¹ It is possible that these findings should be stated conversely, viz. that the joint is so placed as to be affected simultaneously to the greatest advantage by the muscles in question.

whole body in motion as a result of its contraction. For the movement which follows the contraction of a muscle depends not only on the direction of the component of displacement of its resultant, but also on a series of other factors, such as the relative weights of the parts to which each end is attached; the position of the joint concerned at the moment of contraction; the effects of the movement at this joint on the joints at the other ends of the parts; and the influence of the displacements effected on the centres of gravity of the parts and of the body as a whole. The influence of weight depends on the fact that if a muscle passes between two parts of unequal weight, its contraction will move to a greater extent the lighter attachment. Now in the living subject the one part, as a rule, is never infinitely greater in weight, nor is it so fixed by other forces, apart from active muscular contraction, as to be immobile,¹ therefore this double motion always tends to occur. It is almost unnecessary to remark that the accommodation to the action of gravity, is constant in every movement. The displacements effected must be accommodated to the centre of gravity of the part moving, and of the body as a whole, or the centre of gravity must be accommodated to the movement. The last is the case especially where any balancing of the body is required.

In the following pages the action of individual muscles is not what is emphasised; the movements are detailed, and the part which each muscle plays in the several movements is described.

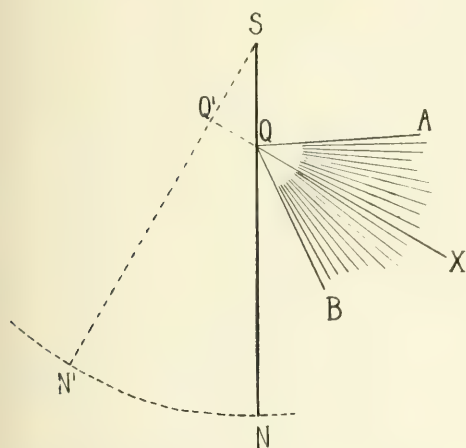


FIG. 8.—DIAGRAM SHOWING THE POSITION OF THE ARM WHEN THE LATISSIMUS DORSI EXERCISES ITS MAXIMUM ACTIVITY.

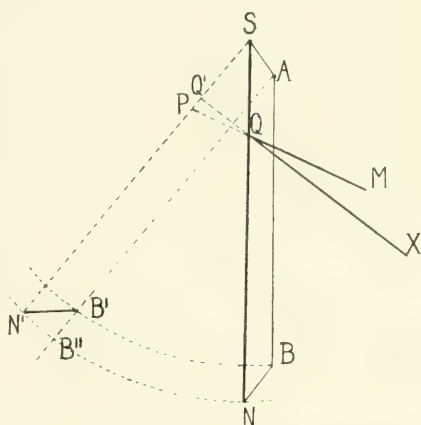


FIG. 9.—DIAGRAM TO SHOW, SN BEING THE AXIS OF THE UPPER ARM, THE ASSOCIATIVE ACTION OF THE TERES MAJOR MQ, THE LATISSIMUS DORSI XQ, AND THE LONG HEAD OF THE TRICEPS AB.

II. The Muscles as Checkers of Movement

Muscles may act as *checkers of movement* in two ways: (1) by active contraction, and (2) by a "ligamentous" action.

The fixation in space of parts of the body by *active muscular contraction* is a very frequent function of muscle, and occurs in order to maintain a part in any given position against a contrary acting force, when it cannot be so maintained by other means. It is effected by the active contraction of the muscle group which is antagonist to the movement tended to. It is possible, therefore, through only short durations of time. The resultant work is only static. It is to be noted, however, that on relaxation of the contracted muscles the movement of the part will occur, and that the velocity and the extent of the movement can be controlled with the same certainty as by the contraction of the muscles which would normally

¹ The muscles of the middle ear and of the eyeball would be excepted

produce it. For example, in leaning on the palms of the hands with the arms slightly bent, the extensor muscles of the elbow are actively contracted against the contrary acting weight of the body. Flexion of the arms, however, of any velocity and through any extent of space, will occur on regulated relaxation of the extensor group, the flexors of the arms being inactive throughout the movement. This aspect of muscular action acquires a further significance, in that it represents the function of muscles which are synergists or fixation muscles to prime movers which pass over two or more joints, for they are brought into the movement as antagonists to those actions of the prime movers which are not required.

The incidence of the limitation of body movement through the *ligamentous action of muscles* may be determined by a comparison of the ellipses of movement of a joint preparation with the muscles intact, and of one in which the ligaments alone are preserved. At the hip-joint, for example, such a comparison demonstrates that the muscular checking mechanism affects the excursions of flexion and adduction. The ellipse of movement of the ligamentous preparation exceeds that of the entire limb in these areas. In the movements of extension and abduction, on the other hand, the ellipses are identical, so that if there be a muscular checking mechanism of these motions, its action must coincide with that of the capsule. The limitation of flexion is caused by the action of the hamstring muscles, and the degree of flexion depends on the state of the knee-joint; for if that joint be flexed, fuller flexion of the hip-joint may be obtained than if the knee is extended. The limitation of the motion is the result of the *shortness of muscle*, referred to as the *passive insufficiency of muscle*, and in function is an approach to that of ligamentous structures.

Other examples might be cited, but in all instances the *shortness of muscle* is apparent only in positions which are unusual, and which are never naturally assumed. This follows from the fact that the muscles concerned, when they have reached their ligamentous action, produce associated movements in the joints over which they pass. So far as the natural and habitual movements are concerned, therefore, muscles have no part in their limitation, for the ligamentous action of muscles is directed solely to the association of different joints in the movement. In movements, however, which are not natural or habitual, muscles which become passively insufficient act as ligaments and check the movement. It is found, therefore, that there are no great individual differences in the range of the movements allowed at the various joints. If an excess of movement is possible in acrobats, dancers, and other similar people, it is confined to those directions in which muscles would normally act as the checking mechanism, and is the result of training at those early periods of life when muscles exercise no limiting action on movements which have not yet become habitual.

III. The Muscles as Forces Retaining in Contact the Articular Surfaces of Joints

Organic joint surfaces, at least those of the diarthroses, will not of themselves remain coincident. They are retained in contact, among other forces, by the action of those structures which form their superficial investment, *i.e.* the articular capsule and the joint muscles. The skin and superficial fascial bands need not for the present purpose be considered.

The articular capsule, however, being incapable of alteration in its length, will, during the movements of its attachments, be in states of varying tension. In those positions which involve approximation of its attachments, the capsule will be slack and, so far as it is concerned, dislocation of the joint surfaces is possible. The capsule, therefore, can only retain the joint surfaces in contact in those positions in which its fibres are fully stretched. In all other positions the surfaces are held together primarily by the action of the muscles, and in the absence

of their action separation of the joint surfaces may be effected; at the hip-joint in semi-flexion, for example, separation to the extent of 1 cm. may occur.

The muscles act in this fashion on a joint, firstly, when they are in active contraction, and it has been determined by Fischer (fig. 10) that the *joint component* (A) of the *resultant of contraction* (F) is in most muscles actually of greater quantity than the *displacement component* (B). Secondly, as a result of their being stretched when functioning as an opposing group, muscles attain a ligamentous action and act as joint approximation forces. This manner of action must become of greater importance when the joint components are placed at acute angles to one another, for then (fig. 11) the joint component (A) of the acting muscle (F) is acting not so as to bring the joint surfaces together, but really so as would force them apart.

Even if none of the muscles of the joint are in active contraction but are at rest, they are, in virtue of their tonicity, still the most powerful factors in holding the joint surfaces in contact. The effect of this tonicity is well demonstrated in the shortening of the limb which occurs as a result of the dislocation of its joints or the fracture of its bones.

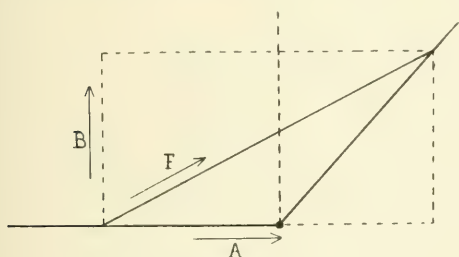


FIG. 10.

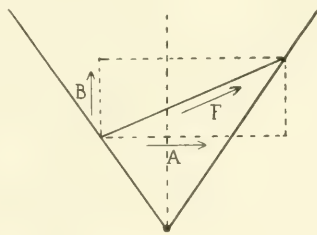


FIG. 11.

DIAGRAMS TO SHOW EFFECT OF MUSCLES ACTING AS FORCES RETAINING JOINT SURFACES IN CONTACT.

A and B, the components of F, the resultant contraction of a muscle.

FASCIÆ

The term **fascia** has been applied in various senses. In this volume it is used to signify those membranous sheets of reticulated or felted fibrous tissue which invest or intervene between the soft parts, especially muscles. In the earliest stages of development the parts are surrounded by, or embedded in, a continuous basis of embryonic connective tissue, the mesenchyme. In certain situations this tissue assumes the form of membranous investing or supporting sheets. In the case of the limbs, for instance, sleeve-like expansions are formed which cover and enclose the muscular masses, and are prolonged between them to find attachment, as intermuscular septa, to skeletal parts. Between the muscular masses, in consequence of the stresses set up by their movements upon one another, the primitive tissue is condensed into sheets, in which the bundles of fibres run mainly parallel to one another, and, as a general rule, at right angles to the direction of the contractile bundles of the muscles over which or between which they lie. These sheets vary much in thickness and degree of resistance in different situations. They may also show variations of density in different parts of their extent, passing over in one situation into the looser forms of connective tissue, or becoming thickened and condensed at another, where they are subject to mechanical stresses in definitive directions. It may be stated here as a general law that all condensations in fascia are probably produced by deposition of bundles of white fibres, which run parallel to the lines of tension set up in it.

Denser sheets of fibrous tissue, in which there is a more or less regular arrangement of parallel-running strong white fibres, are sometimes termed **aponeuroses**. While there is no structural distinction between a dense fascial sheet and an aponeurosis, the latter term will be used here in the sense of a spread-out tendon,¹ and reserved, therefore, for sheets of tendinous appearance, by means of which muscle sheets find attachment to skeletal or other parts. It must be noted, however, that the distinction cannot always be strictly maintained, as a fascia of investment may pass directly into an aponeurosis of attachment, while both tendon and aponeurosis may be continuous with fascial expansions.

Fasciæ are generally distinguished as *superficial* and *deep*. To avoid the confusion which results from the inclusion among superficial fasciæ of membranous expansions on the surface of muscular masses, the term superficial fascia will be here limited to the layer of loose tissue of varying density which is placed immediately under the skin all over the body.

Superficial Fasciæ.—The subcutaneous fascia is a layer of loose tissue which contains the subcutaneous fat, and in some regions superficial muscles. It varies in density in different situations, sometimes being quite loose and unattached to deeper structures, but sometimes dense and firmly bound down. The subcutaneous fatty tissue is deposited irregularly over the body, but is everywhere present except in the eyelids, penis, and scrotum. It occupies the more superficial lamellæ of the fascia immediately under the skin, but below this there is generally a deeper layer comparatively devoid of fat, in which the trunks of the cutaneous vessels and nerves are found. When the fat becomes absorbed, the stroma in which it was deposited is still left and its meshes approach one another, so that in lean subjects a more fibrous condition of the superficial fascia is found than in others. A detailed account of the superficial fascia belongs rather to a work on practical anatomy than to the present volume. The deep fasciæ more strictly connected with the muscles will alone be fully dealt with.

Deep Fasciæ.—Under this head are included the stronger layers or sheets of fibrous tissue which lying close to the muscles invest them, dip down among them, or otherwise intervene between them. The principal investing fasciæ are those which encase the muscles of the limbs, binding them down in a common sheath, and connected directly, or by septa, with the bones.

Part of the deep fascia in the neighbourhood of the larger joints, as at the wrist and ankle, becomes strengthened into tight transverse bands which serve to hold the tendons close down to the bones, and hence have received the name of *retinacula* or *annular ligaments*. The reason for the formation of these bands may be sought in the tendency for the tendons, when the muscles contract, to draw away from the bones so as to take up the shortest course between origin and insertion. It is obvious that transverse stresses will be induced in the covering connective tissue which lead to the development of transverse bundles of white fibres which form the bands.

Synovial Sheaths and Bursæ.—In situations where moving parts play upon one another, as where a tendon, or the skin, glides over a projecting bony surface, cavities containing fluid are developed in the areolar connective tissue. These are known as *bursæ*. Under the skin in various positions large simple or irregular bursæ containing a clear fluid occur, sometimes known as *bursæ mucosæ*. In other situations, as between tendons and bones or fascial bands, synovial

¹ This usage is more correct than that which applies the term to any fibrous membrane of tendinous character. The word *νευρον* originally signified tendon or sinew, and *ἀπο-νευρωσις* means the "sinewing off" of a muscle, *i.e.* the end of a muscle where it becomes tendon, or the tendon where it spreads out to join the muscle.

structures are present which are produced in much the same way as the synovial membranes of joints. They contain synovia, and are named *bursæ synoviae*. Where tendons run in fibrous sheaths, or in special osseo-fibrous canals, the synovial spaces have a saccular or tubular form. In the embryo, even before movement of the tendon sets in by the contraction of the muscle, the primitive connective tissue becomes condensed round the tendon to form a sheath. The continuous sheath or embedding substance takes on a mucous character immediately round the tendon, while the more peripheral layers are condensed into a fibrous sheath. When the sliding of the tendons sets in, a cavity is produced by the resolution of the mucous tissue into primitive synovia. In this way we have a fibrous sacular or tubular sheath lined by a synovial layer which is invaginated by the tendon. In the simplest sheath of this kind there is a continuous membrane or *meso-tendon* connecting the tendon with the wall of the canal. Between the layers of this, blood vessels are conveyed to the tendon, and on the analogy of the serous cavities we speak of a parietal and a visceral synovial layer. Parietal and visceral layers are of course continuous with one another at the extremities of the sheath. Here provision is made for the displacement which must occur in the movements of the tendon, by the return upon it for a certain distance of the parietal layer, before it passes into the visceral layer. In long osseo-fibrous canals, as in the case of the digital sheaths in the fingers, where the tendons glide for a considerable distance, the returning parietal layer becomes proportionately more voluminous, and is folded in round the tendons to form a sort of second sheath. The circular fold is taken up or let down again in the movements of the tendon, and thus the danger of rupture is avoided. In such cases a continuous meso-tendon is not present. It is reduced to membranous bands, quadrilateral or triangular, or to elongated threads (*vincule vasculosa*) conveying vessels to the tendon. These last always and necessarily run obliquely, and the distance between the fixed and movable attachments when doubled will clearly give the measure of the sliding movement of the tendon.

Some of the synovial sacs and sheaths of tendons in the vicinity of joints communicate freely with the articular cavities. The communication is, however, in most instances secondary, not primary. In the fœtus and new-born children, in some situations, the synovial sheaths are more numerous than in the adult. Individual tendons are provided with separate investments which run together by the disappearance of the septa between them, so as to produce complicated common sheaths for a number of tendons. In the same way many of the bursal sacs which will be noticed do not appear until after birth, when they are produced apparently in response to local conditions of pressure. Many of these sacs are always and normally present in certain positions. In other regions they are not invariably developed. There seems to be a regular gradation from simple cleft-like spaces up to the synovial lined cavities.

GENERAL ACCOUNT OF THE DEVELOPMENT AND MORPHOLOGY OF THE SKELETAL MUSCLES

In descriptive Myology it is obviously necessary to take up the individual muscles regionally, and to describe them in the order in which they are displayed in a dissection of the regions. But it is equally necessary for a proper understanding of the complexities of the muscular system to group them morphologically. A knowledge of the developmental history of the muscles enables us to reduce the great mass of descriptive material to some sort of scientific order. The study of

the muscles becomes easier, and more interesting, if the complicated arrangements in the adult can be explained in terms of the simpler conditions in the embryo. Now, for reasons which will appear presently, the relation of nerve and muscle is an index to the developmental origin of the muscles and to their primitive position in relation to the skeleton. It is also an important guide to their homologies with the muscles in lower forms. The data are in great part available to the student in ordinary dissections, and once the morphological reasons for the nerve distribution are understood, an analysis of the muscles in terms of nerve supply becomes a considerable aid in organising a knowledge of the descriptive facts. In the pages which immediately follow, a general account will be given of the development and morphology of the muscular system. In the section on descriptive Myology further detail will be given for the individual muscles, and the various muscle systems.

The whole of the skeletal musculature arises from the mesoderm. From the developmental point of view we have to distinguish the muscles of the trunk, the muscles of the head, and the muscles of the limbs. The trunk muscles arise entirely from the myotomes, the head muscles, with the exception of the eye muscles, from the mesoderm of the branchial arches, while the limb muscles appear in higher forms to arise independently in the mesenchyme of the limb buds, although they are to be considered as developed in phylogeny from the myotomes like the trunk muscles.

The Muscles of the Trunk.—The myotomes are derived from the paraxial segmented mesoderm. Each primitive segment (see Vol. I., p. 51) consists at first of epithelial cells enclosing a cavity—the *myocœle*. It is somewhat triangular in cross section, presenting medial, lateral, and ventral walls. The cavity becomes occluded by cells budded off from the epithelial walls. The greater part of the inner wall and the ventral wall then become resolved into mesenchymatous tissue. This, along with the cells in the cavity of the segment, is carried medianwards to form the sclerotome from which the axial skeleton originates (see Vol. IV., Part I., p. 7).

The dorsal part of the medial wall of the hollow segment now grows ventralwards on the medial face of the outer wall, until it reaches the ventro-lateral angle, where it becomes fused with the inturned extremity of the outer wall. The cavity is thus reduced to a narrow cleft between the two layers. The inner wall is now converted into primitive muscle tissue (see Vol. I., p. 56), and constitutes what is known as the muscle plate in contradistinction to the outer wall which is named the skin plate, because it was at one time believed that it was resolved into mesenchyme underlying the surface ectoderm. The fate of the outer plate is still a matter of dispute, but it would appear that it also is converted into muscle tissue, and the two plates, when fused together, with obliteration of the myocœle, form the *myotome*.

In certain lower vertebrates the myocœle is continuous in early stages with the general cœlom by a hollow stalk concerned in the formation of the excretory tubules. The general cœlom is bounded by somatopleure and splanchnopleure, and it is important to note here that while the mesoderm of the splanchnopleure retains the power to produce myogenic tissue, that of the somatopleure has no such property. As will be explained in the immediately succeeding paragraphs, the whole musculature of the trunk is produced from the walls of the myocœle by ventral outgrowths which extend into, and round, the body wall.

Each myotome is roughly rectangular in shape, and is separated from the myotomes which precede, and succeed it in the series, by septa of primitive connective tissue. The septa next disappear, and the myotomes fuse into a continuous column in which all trace of the original segmentation is lost, except

in the deeper parts of the column. The myotomes before they fuse are seen to send out processes which extend ventrally in the body wall with the ribs. The dorsal edge of the myotome column also extends dorsalwards, and is carried towards the median plane by the formation and closing in of the neural arches. The ventral processes are likewise fused, but part of the myogenic tissue is engaged between the ribs and retains the original segmentation. The ventral edge of the sheet is early separated off as a longitudinal column, the future rectus muscle, and here traces of segmentation are preserved. The lateral sheet is thus divided into a dorsal and a ventral portion, usually known as the *dorso-lateral* and *ventro-lateral* sheets. The dorso-lateral sheet, or original myotome column, early shows a longitudinal furrow which divides it into lateral and medial columns. From these the dorsal muscles of the trunk are developed by tangential and longitudinal cleavage of the common mass. The columns are continued to the skull, and

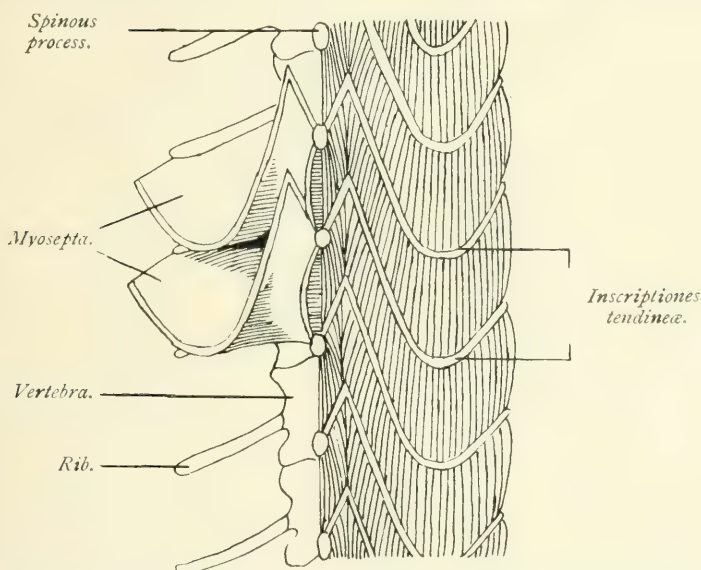


FIG. 12.—DORSAL MUSCLES OF THE TRUNK OF *Cryptobranchus japonicus*, HALF SCHEMATIC. (After Seiho Nishi.)

therefore produce also the spino-occipital muscles. The ventro-lateral sheet yields the muscles of the body wall; they are separated off mainly by tangential cleavage of the sheet into lamellæ.

In fishes and amphibians (fig. 12) the fusion of myotomes does not occur. The myomeres form continuous zonular bands in which the individual fibres run parallel and are attached by their extremities to the myosepta between which they lie. These appear on the surface as tendinous intersections. The distinction between dorsal column and ventral sheet is marked by a longitudinal furrow, but only in the reptilia does a complete separation between the dorsal and ventral musculature become established. In Urodeles the dorsal column is more or less undivided, but the ventral sheet begins to show delamination into a superficial and deep layer. In Anura and Gymnophiona the dorsal column begins to be divided up, and in the latter superficial lateral, and deeper medial tracts are differentiated. These divisions correspond not to the medial and lateral columns as defined by the nerve supply in mammals, but to the separation of an ilio-costalis system from the common mass. It is the same division as appears in human development. In the higher reptilia we see a further division of the medial tract into longissimus and transverso-spinalis columns. Only in higher reptiles and mammals does the ilio-costalis become divided into slips attached to the ribs. In *Sphenodon* it is still typically segmented (fig. 13). In this primitive reptile the longissimus

and transverso-spinalis columns also retain in their superficial parts the original segmentation, but in lizards they have become divided into serially arranged slips. The ilio-costalis and longissimus columns are both supplied by the lateral branches of the spinal nerves, the transverso-spinalis and spinalis systems by the medial branches, and thus in mammals we have established the grouping of the muscles in two columns, one supplied by lateral, the other by medial branches.

In human development the ventral processes of the myotomes become fused to form one continuous sheet superficial to the ribs, and another on their inner aspect, while part is engaged between the ribs. Beyond the ends of the lower ribs the same tripartite division occurs, so that the abdominal wall consists of three layers (fig. 14), the middle being spread out in a sheet uninterrupted by the ribs. The rectus column is differentiated before the body wall closes in ventrally, so that the two muscles at first stand wide apart. In the outer and middle layers of this trunk musculature the fibres are disposed obliquely, but in opposite directions.

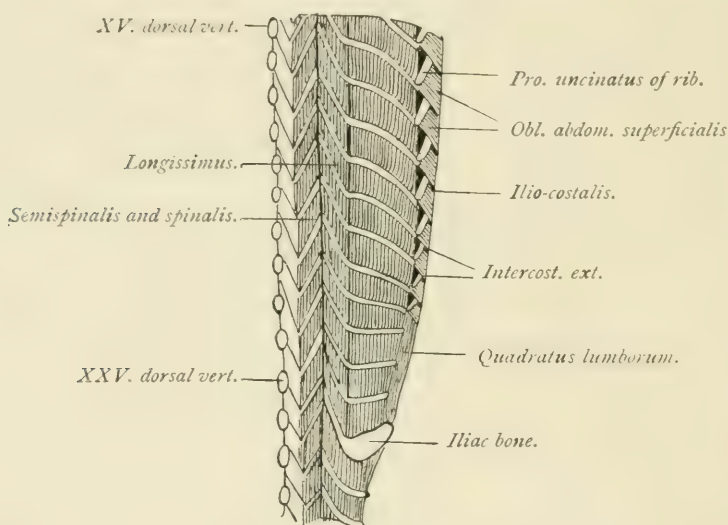


FIG. 13.—DORSAL MUSCLES OF *Sphenodon punctatus* IN THE REGION OF THE POSTERIOR PART OF THE TRUNK. (After Seiho Nishi.)

The guiding line to the ilio-costalis stops at the edge of the figure; it should have been carried over the rib to the broad ilio-costalis column.

In the deep layer they are transverse. The thoracic part of the ventral sheet yields the muscles of the thorax proper and those of the abdominal wall. These last gain attachments to the pelvic girdle, and thus entirely enclose the abdominal cavity. In the cervical and lumbar portions of the sheet the results are different. In the neck (fig. 15) the ventral rectus system gives rise to the infrahyoid and certain suprahyoid muscles. The remainder of the ventro-lateral sheet consists of two portions: one latero-dorsal which gives rise to trunk muscles proper (scaleni and prevertebral group of muscles); the other latero-ventral which belongs to the limb bud, produces muscles attached to the limb girdle, and is theoretically continued into the limb bud to give origin to the muscles of the free extremity. A further feature of difference is that the upper five myotomes in the neck extend medianwards on the ventral aspect of the vertebral column, and give rise to the prevertebral system of muscles. In the lumbar region (fig. 16) only the dorsal part of the ventro-lateral sheet, *i.e.* that part which gives rise to trunk muscles, is represented; the limb girdle portion of the sheet is entirely absent, and the

remainder is, as it were, swept into the hind limb bud. The dorsal remnant of the sheet gives rise to the intertransverse muscles and the quadratus lumborum.

In the limb buds the myogenetic material is disposed in dorsal and ventral lamellæ. In the case of the fore limb, both of these spread proximally over the trunk so as to cover in the proper trunk muscles. The dorsal sheet gives origin to the latissimus dorsi, the ventral to the pectoral muscles, and also to the panniculus carnosus, of which, however, only vestiges exist in man. The muscles of the trunk are all laid down by the seventh week in the human embryo.

The facts that the myotomes undergo fusion, so that practically all trace of segmentation is lost and that there is considerable shifting of myogenic material during development, render the reference of individual muscles to the myotomes from which they took origin difficult. It would be impossible but for the circumstance that at an early stage of development each myotome is connected

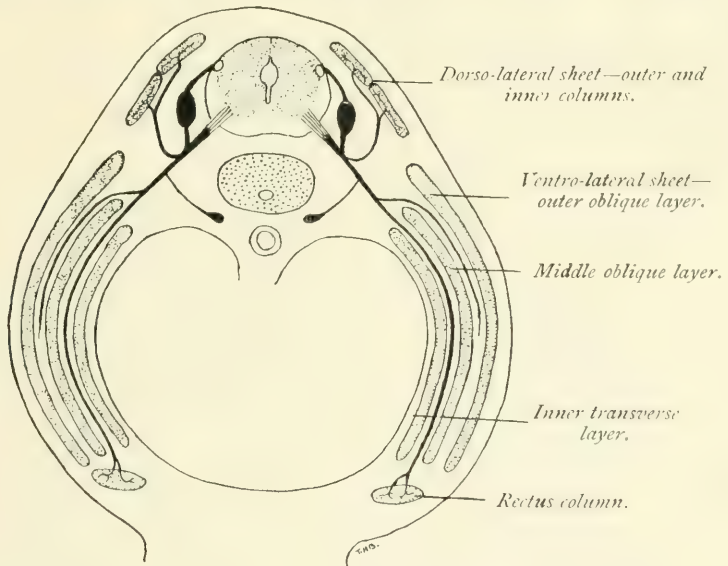


FIG. 14.—IDEAL SECTION OF AN EMBRYO ABOUT 15 MM. LONG, SHOWING ARRANGEMENT OF MUSCLE SHEETS DERIVED FROM THE THORACIC MYOTOMES.

with a segmental motor nerve, and that the connexion once established is a permanent one. The segmentation of the nerves is only secondary to the primary mesodermic segmentation, and that again was determined in phylogeny by the division of the primitive cœlom. The circumstance that the nerves emerge between the vertebræ results in their segmental succession being maintained, while that of the muscles disappears in great part.

It is not necessary to enter here on the controversial question whether the neuro-muscular connexion is a primary one. The doctrine has sufficient support in observed fact to make it a tenable hypothesis. But even if the connexion be a secondary one, it is established at so early a stage in development that it is possible to found a complete morphological system, at least as far as the trunk is concerned, on the nerve supply without fear of serious error. It is generally admitted that the nerve supply to a muscle is the best index to its morphology. But it is not infallible, and certainly must be controlled by thorough embryological observations. Such observations prove that a considerable shuffling of the myogenic material occurs during development. Some observers in this difficult field of research have convinced themselves that muscles which have become shifted in position during development acquire nerves of supply belonging to the new

position. But the fact that there is much intermingling of myogenic tissue from different sources in development makes conclusions on questions of this kind very difficult and uncertain. Further, observations by Maurer, Bardeen, Müller, and others suggest that the segmental motor nerves are distributed from the first to the two adjoining myotomes between which they lie. It is known that in fishes, when the musculature retains its metameric arrangement, the ventral extensions of the myotomes to the fins are supplied by more than one segmental nerve. Such considerations necessitate reservations; but there is another difficulty which presents itself in the case of the limbs. It would seem that individual nerve fibres may be variously distributed in the nerve plexuses; that they take, or may take, different routes to their destination. Conclusions regarding the homologies of the limb muscles below the plexuses must always take account of this possible fallacy, and most workers on the homologies of the limb muscles use nerve supply with reserve. For the trunk, however, the nerve supply is in general a safe index to the source of the myogenic tissue from which the muscle is developed, and in the following account it will be assumed that according to the segmental nerves involved in the supply of a muscle, we may conclude the number and position of the myotomes from which it has taken its origin. Instances occur in the development of the muscular system in man in which the muscles appear to arise independently, although in

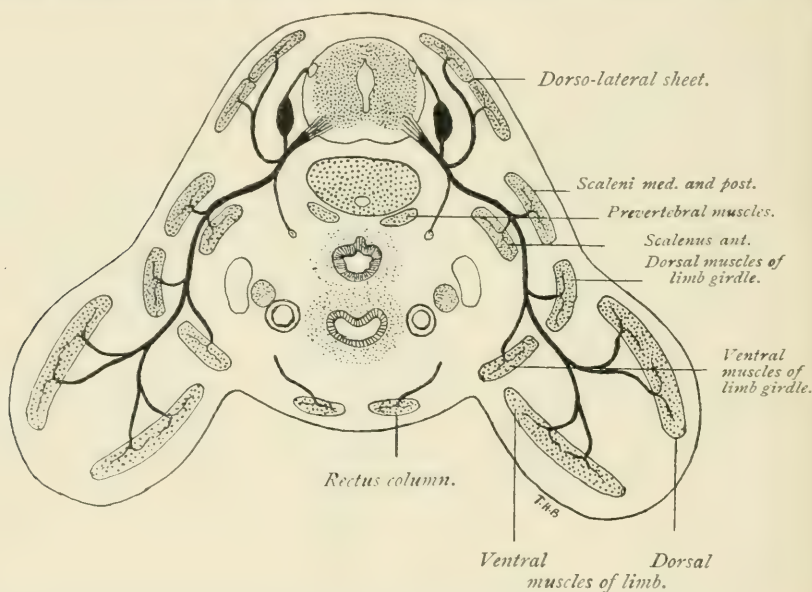


FIG. 15.—IDEAL SECTION OF AN EMBRYO ABOUT 15 MM. LONG, SHOWING ARRANGEMENT OF MUSCLE RUDIMENTS IN THE NECK AND ANTERIOR LIMB BUDS.

lower forms they are clearly of myotomic origin. These cases are probably to be explained by that abbreviation or condensation of development, of which so many examples are to be found in the embryological history of the higher vertebrates.

Each segmental nerve, after emerging from its intervertebral foramen, gives a dorsal branch which passes backwards between the transverse processes, and is then continued in the body wall as its ventral trunk. The dorsal branches are distributed to the dorso-lateral mass, the ventral to the ventro-lateral sheet of muscles. An examination of the relation which the ventro-lateral muscles bear to the ventral nerve trunks shows that certain muscles lie medial, others, and the larger number, are placed lateral to the nerves. This distinction of position will serve for a further division of the ventro-lateral muscles of the trunk (figs. 14, 15, 16).

The Muscles of the Head.—In the region of the head the plan on which the muscles of the trunk are formed is modified. In the embryo of some of the

most primitive vertebrates, apparent myotomes occur in the head region and extend as far as the anterior end of the notochord, although they undergo speedy reduction. It may reasonably be concluded, therefore, that at some stage in phylogeny the head was segmented at least as far forward as this level.

Some morphologists argue that the same is probably true of the parts still further forward. According to the enlightening hypothesis of Fürbringer, the portion of the head which shows segmentation in the early embryos of the lowly vertebrates, represents part of the axis of the trunk added to the primitive head. The addition of trunk elements took place in two steps. The first step, which is common to all living vertebrates except Cyclostomes, added what he names the occipital segments (*t, u, v, w*, fig. 18). The second step, taken only in some vertebrates, added another series of trunk segments (*x, y, z*, fig. 17). In Man, and the Amniota generally, no traces of segmentation proper occur, except at

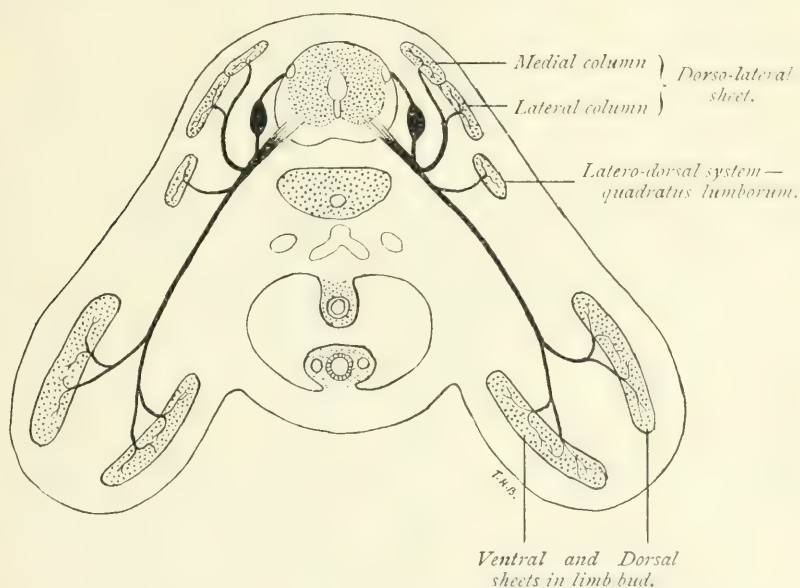


FIG. 16.—IDEAL SECTION OF AN EMBRYO, ABOUT 15 MM. LONG, SHOWING MUSCLE RUDIMENTS DERIVED FROM THE LUMBAR MYOTOMES.

the very hinder part of the skull, and the segments there appearing, three in number (*x, y, z*), are the trunk segments which have been included in the head in the second stage of its extension at the expense of the trunk. On the assumption, then, that the chordal part of the head was once segmented, we would expect that, with the formation of a rigid brain box in which the parts are fixed, the dorsal musculature, which in the trunk is concerned in the movements of the vertebræ on one another, would not be required. The myotomes, therefore, disappear, and the only remnants of the ancient dorsal myotomic mesoderm are probably to be recognised in the myogenic tissue which gives origin to the eye muscles. The trunk myotomes most recently added still survive in attenuated form, and probably give rise to the muscles supplied by the hypoglossal nerve.

In the embryo of Elasmobranchs the eye muscles develop from the epithelial walls of three hollow structures resembling myotomes (fig. 18). Two of these are connected ventrally by stalks with the splanchnocœle of the head and they occupy the mandibular and hyoid arches respectively. The third lies in front of the mandibular arch, is connected with the cavity of the other side, but

is unconnected with the splanchnocoel. This last mesoderm mass is associated with the third nerve, and gives origin to the ocular muscles supplied by that nerve. The two hinder rudiments are related to the fourth and sixth cranial nerves respectively, and give rise to the muscles supplied by them. In higher vertebrates the hollow rudiments are replaced by solid masses which arise in the mesenchyme without any appearance of segments, but in the same relative positions as the "head cavities" described in the Elasmobranch embryos. In the rabbit, according to Edgeworth, the three groups of cells are, in the earliest stages, separate from one another. In the pig (Reuter) and in Man (Lewis) the muscles all arise from a common premuscle mass which differentiates in the mesenchyme, but is penetrated by the same three nerves which supply the ocular muscles in all vertebrates.

The dorsal musculature is thus absent, or greatly reduced, in the head region, but a system of muscles not represented in the trunk is evolved in the head to act

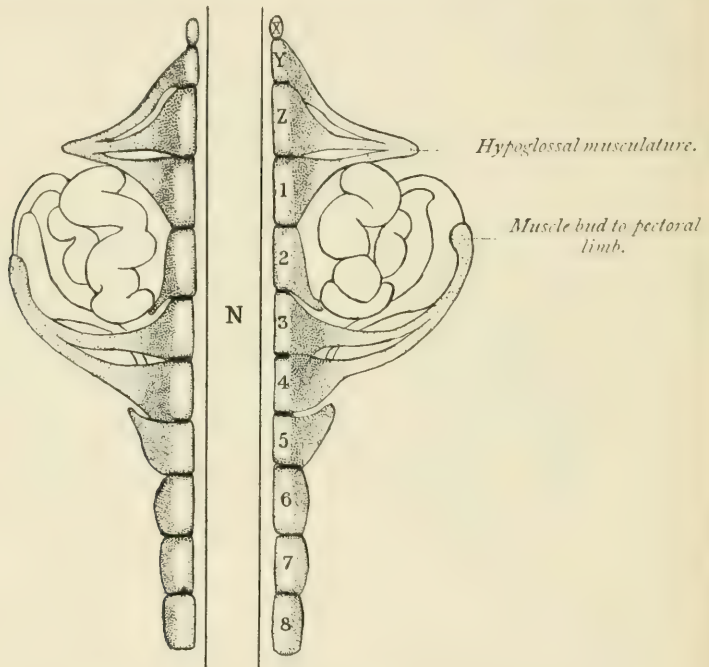


FIG. 17.—DORSAL VIEW OF THE ANTERIOR MYOTOMES OF AN EMBRYO OF PROTOPTERUS. (After Graham Kerr.)

X, Y, Z, occipital myotomes supplied by hypoglossal nerve; 1, 2, etc., trunk myotomes; the pronephros is represented in outline; N is the notochord.

on the movable parts of the gill arches. They are developed from the continuation forwards into the head of the unsegmented mesoderm, which lies ventral to the myotomes, and does not give rise, as we saw, to any somatic musculature in the trunk. In lowly vertebrates (Elasmobranchs) the splanchnocoel of the head lies ventral to the fore-gut, as in all other vertebrates, and as in them gives rise to the pericardium. But the cavity is continued laterally and dorsally into coelomic pouches occupying the branchial arches between the gill clefts. Now, if there were no gill clefts, the dorsal extensions of the coelomic cavity would have the form of continuous dorsally directed culs-de-sac. But these are, as a matter of fact, interrupted by the clefts (fig. 18), and thus converted into a number of pouches between the clefts. The two walls of the pouches come together, and from the solid stalks thus formed the muscles of the several arches develop. In

the mandibular and hyoid arches the pouches are continuous with the *head cavities*, but further back they have no connexion with the myotomes. The myotomes, as we have seen, shrink and disappear from before backwards—and it appears that hinder myotomes move forward to take the place of those which disappear at the forward end of the series. In consequence of this migration of the myotomes it follows that myotomes and branchial cœlomic pouches, which stand in apparent relationship, do not correspond in segmental position. The segmentation of the branchial mesoderm thus established does not necessarily correspond to the primary segmentation of the paraxial mesoderm of the trunk.

In higher forms the cœlomic pockets have vanished, and the pericardial cœlom lies entirely ventral to the pharynx. The branchial arches are occupied by a continuous mesenchyme. This gives rise to the connective tissue and skeletal elements of the arches, and in each arch solid masses of cells are differentiated, which are the rudiments of the branchial muscles. The arches are supplied with motor nerves from the lateral group of motor nuclei in the hind

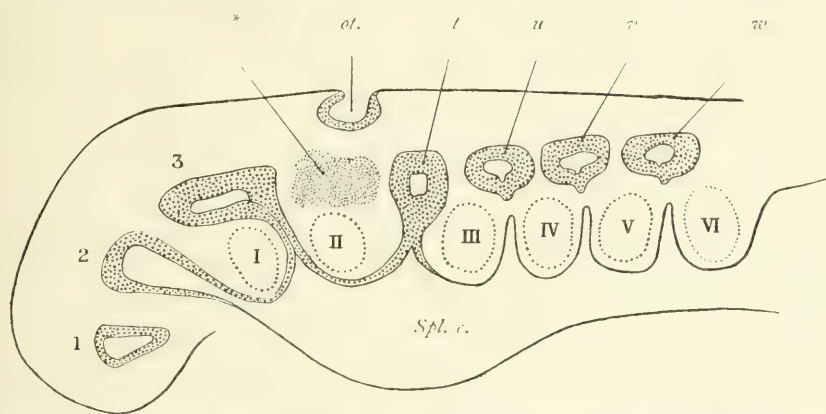


FIG. 18.—DIAGRAM TO ILLUSTRATE THE ARRANGEMENT OF THE MESODERM SEGMENTS IN THE HEAD REGION OF A YOUNG ELASMOBRANCH EMBRYO. (After Agar and Graham Kerr.)

ot., otocyst; *Spl. c.*, splanchnocœle; 1, 2, 3, anterior myotomes; I, II, etc., visceral clefts; *t, u, v, w*, occipital myotomes; *, "fourth" myotome of van Wijhe.

brain through the 5th, 7th, 9th, 10th, and 11th cranial nerves, which are distributed to the arches in that order. In the Amniota the branchial apparatus is greatly reduced, but in the distribution of these branchial nerves to the muscles we have a valuable index to the origin of the muscles. Thus we refer the muscles of mastication supplied by the trigeminal nerve to the mandibular arch, the facial muscles supplied by the seventh nerve to the hyoid arch, while the muscles of the pharynx and larynx supplied by the glossopharyngeal and vagus nerves belong to the branchial arches proper.

Another special feature of the musculature in the head region is the degree to which the visceral musculature of the fore-gut is specialised. The problem involved in the development of these muscles will be alluded to later. At this point it need only be stated that the pharyngeal and palatal muscles, from the developmental and morphological points of view, are strictly visceral muscles, while the branchial muscles proper are to be classed as somatic.

The Muscles of the Limbs. In Selachians and some other fishes, the limb muscles are derived from definite outgrowths from the myotomes, there being two buds from each myotome. Connexions are established between the

buds, so that there is a certain intermingling of the myogenic tissue derived from the several segments. The buds extend into the developing paired fins, and divide into dorsal and ventral sheets which give rise to the dorsal and ventral radial muscles of the fins. In some other cases, among the lower vertebrates, the buds break up into their constituent cells before giving rise to muscle cells; in others there are no distinct buds, but the myogenic cells are budded off diffusely from the myotomes and are carried into the limb buds. This last seems to be the condition of affairs in the higher vertebrates. The actual migration of cells from the myotomes has been observed in few cases, and some authorities hold that the muscles arise quite independently in the mesenchymatous core of the limb bud. Ingalls in a 4.9 mm. human embryo gives some positive evidence on the matter. In the case of both limb buds the ventral ends of the myotome processes are broken up as they approach the limb, but actual muscle buds were detected extending from the lateral aspect of the fifth cervical myotome.

The developmental processes are so condensed and abbreviated in higher vertebrates that the apparent absence of a definite connexion between the limb muscles and the myotomes is not sufficient to justify their being placed in a different morphological category from the limb muscles in lower vertebrates. We therefore must regard the myogenic material in the limb buds as myotomic in origin, but without any trace of metameric arrangement. The nerves, however, as in the trunk, do preserve their segmental distribution to the limbs, at least as far as the limb plexuses. The redistribution of nerve fibres in the plexuses is to be correlated with the merging of the myotome processes as they enter the limb. But it has been demonstrated that the motor nerve fibres contributed by the segmental nerves are arranged in serial order from the original cranial border (radial or tibial) to the caudal border (ulnar or fibular). If the muscular tissue supplied by the segmental nerves be imagined as dissociated from the individual muscles, and rearranged according to nerve supply, we should have a series of radial bands of muscle from radial (or tibial) to ulnar (or fibular) margin of the limb, very much as we see them in the fins of Selachians.

The appearance of muscles in the limb buds is heralded by the differentiation of cells which have larger nuclei than those of the mesenchyme, and protoplasm which stains more intensely with eosin. These myogenic cells multiply and arrange themselves round the axial core of cells concerned in the formation of the skeletal elements in two lamellæ, a dorsal and a ventral. Out of these two plates of premuscle tissue the various extensor and flexor muscles are formed. The dorsal and ventral branches of the nerve cords enter the dorsal and ventral lamellæ respectively and divide up in them. The blastemal tissue, by a series of histogenetic changes, becomes converted into fibrillar muscular tissue. According to Bardeen, these changes begin round the terminal branches of the nerves, so that each muscle is developed from a separate germ in the common mass of myogenic tissue. From the central point in each case differentiation proceeds proximally and distally towards the future origin and insertion. The myogenic cells are mingled with the ordinary mesenchyme cells of the limb bud. The mesenchymatous tissue gives rise to the connective tissue structures which attach the contractile masses to the developing skeleton, as well as to the fascia which invests the muscles, the intermuscular septa, and the tendinous expansions. The differentiation of the individual muscles begins at the base of the limb and proceeds distally. This is true in both extremities, but the muscles of the leg are more tardily developed than those of the arm. All the muscles are recognisable by the sixth or seventh week of development.

In the distal parts of the limbs there is an obvious general correspondence

between the muscles of the two extremities, and a study of the muscles in the more primitive marsupials, in the monotremes, in the reptiles and amphibians, makes it possible to reconstruct the primitive common plan on which the individual muscles were laid down. We can, to a considerable extent, restore the phylogenetic stages through which the musculature has passed. At the base of the limbs this is much more difficult, because there is marked divergence in the arrangement of the muscles in the two limbs. This has resulted from the changes in the form of the girdles, which followed specialisation of function. The pelvic girdle became fixed to the vertebral column, while the pectoral remained free dorsally. Hence muscles derived from the ventro-lateral sheet present themselves in connexion with the pectoral girdle, which are suppressed in the case of the fixed pelvic girdle. Again the fixity of the pelvic girdle, and the changes resulting from the differing functions of the hind limb, determined changes in the arrangement of the muscles acting on the hip-joint, as compared with those acting on the shoulder-joint. These differences were established very early in phylogeny, and the further specialisation of the shoulder girdle, with the regression of the coracoid in higher forms, accentuated the early differences. It is thus impossible to determine, except in a general way, the serial homologies of the muscles at the base of the limbs. In thigh and arm the resemblance between the muscles of the two limbs is much closer. On the extensor aspect in both there is a muscle composed of several parts, attached below the middle joint by a common tendon, and in both extremities there are long heads arising from corresponding points on scapula and iliac bone. In all tetrapodal vertebrates the general plan is the same, but in the lizards the crural extensor has an iliac head which probably corresponds to the gluteus maximus and tensor fasciæ femoris combined, and the mass on the femur is not subdivided as yet into the four separate parts. The adductor groups in the two limbs are also comparable so far, that the adductor longus and brevis and part of the magnus correspond to the coraco-brachial group. The flexor groups while generally comparable are arranged on somewhat differing plans.

In the middle and distal segments of the limbs the resemblances are still greater, and homologies, both general and serial, can be more certainly defined. The dorsal and ventral laminae are resolved into extensor-supinator and flexor-pronator masses, and each of these shows divisions into corresponding parts. The ideal primitive arrangement may be reconstructed as follows:—

A. *Extensors*.—The common extensor mass shows a division distally, but not yet proximally, into a central digital and two marginal portions. The marginal parts find attachment below in the region of the carpus, or tarsus, and thus act on the distal joint moving the hand, or foot as a whole. The central digital portion shows a superficial long, and a deeper, more distal short portion. Both these parts end on tendons which divide up into slips distributed to the digits.

B. *Flexors*.—The flexor-pronator mass is stronger than the extensor. Three phases may be described: I. Again a primary division into a central and two marginal portions is established, and the latter, as before, are attached in the region of the carpus or tarsus, and move the hand or foot as a whole. This condition is realised in the fore limbs of *Ornithorhynchus* and *Echidna*, but not in their hind limbs.

II. In urodele amphibians and lizards the digital mass shows division into two layers, superficial and deep. In urodeles the deep layer already shows subdivision, but for our present purpose this detail may be neglected. Both layers of the digital mass end below upon a common tendinous plate, the *primitive* palmar or plantar aponeurosis. The prominent heel process has not yet appeared to complicate the picture in the foot. The marginal portions are also

connected with the marginal parts of the connective tissue mass in palm or sole, and through this obtain attachments to skeletal structures. Beneath the digital layers in the middle segment of the limb a third deep layer has been separated off, consisting of fibres extending between the bones. It is the primitive pronator muscle. A muscle has also been detached proximally from the deep digital layer. It extends over the middle joint and, in addition to ordinary flexion, it provides for lateral or rotatory movements at that joint. It is the pronator teres muscle in the arm, the popliteus in the leg. Returning to the common digital flexor it is to be noted that the fibres of the superficial layer extend proximally over the middle joint, to be attached to the distal extremity of the bone of the proximal segment, while the fasciculi of the deep layer are fixed to one or other, or both, of the bones of the middle segment. The common tendon on which all the fasciculi end divides below into slips, one for each digit, and these are attached to the terminal phalanges.

III. The tendon is now resolved into two layers superficial and deep, corresponding to the two layers of the fleshy mass. This delamination involves the digital slips, but does not extend further than the metacarpo- or metatarso-phalangeal joints. It thus comes about that the superficial layer of muscle—palmaris or plantaris—is connected with the superficial layer of the primitive aponeurosis, now the *definitive* aponeurosis; while the deep layer—flexor communis—is continuous with the deep lamella of the primitive aponeurosis, now the tendon of the common deep flexor. Each tendinous lamella has digital slips and the two slips of each pair are separate proximally, but fused upon the digits. Now between the two layers, and attached to the deep surface of the definitive aponeurosis, there is a fleshy mass which divides distally into muscular slips, one for each digit, as well as into marginal slips for the border digits (fig. 19). These last are simple, but each central slip divides into two fleshy heads which embrace the deep tendon as it passes on to the digit. Convert the greater part of the short flexor muscles and their two heads into tendon, and we have perforated tendons, embracing the deep or perforating tendons. At first the long tendon on each digit is embedded in connective tissue, and with this the digital slip of the definitive aponeurosis is fused. A serous space next develops, isolating the tendon from its sheath. The perforated tendon comes to be included in this sheath with the long tendon, and finds insertion on the second phalanx deep to it. One point more and we have realised the arrangement of the flexor brevis digitorum of the foot. Certain digital short flexor slips remain attached to the deep lamella of the primitive aponeurosis, *i.e.* the common tendon, and constitute the deep head—only occasional in man—of the flexor brevis digitorum.

In the leg the deep part of the common digital flexor mass is resolved into a tibial and a fibular portion, while the superficial part becomes the plantaris, and probably also the medial head of the gastrocnemius. The lateral gastrocnemius and soleus are derived from the fibular marginal muscle. They are inserted into the os fibulare (calcaneus), and this has developed the prominent heel process which breaks the continuity between the muscles of the calf and the plantar fascia.

In the arm things go a little differently. The superficial lamella of the common flexor becomes the palmaris. Its tendon remains in continuity with the palmar aponeurosis. The deep common flexor now becomes delaminated into flexor sublimis and flexor profundus, and the splitting involves both belly and tendon. The superficial palmar short flexors have meantime been freed from the covering palmar aponeurosis, but remain attached to the common tendon, and when this is resolved into a part connected with the sublimis, and a part connected

with the profundus, the short flexors remain in continuity with the sublimis. The short flexor bellies become entirely tendinous, and are now the perforated tendons of the flexor digitorum sublimis. The fleshy part of the short superficial palmar flexor does not, however, entirely disappear. It gives rise by its marginal parts to the superficial muscles of the thenar and hypothenar eminences (fig. 19).

The deeper muscles of both hand and foot may be derived from a complex system of short digital muscles which occur in lizards and urodele amphibians. Among mammals they are only seen in anything like their full complement in primitive marsupials and monotremes. *First*, immediately beneath the superficial short flexors there is a series of muscular slips connected with the tendons of the long flexor. These are the lumbricals, and it is probable that there were originally two to each digit. *Second*, there is a still deeper stratum of four muscles so disposed as to adduct the digits to the middle line of hand or foot. In marsupials they are attached to, and radiate from, a central tendinous raphe. *Third*, separated from these adductors by the deep branch

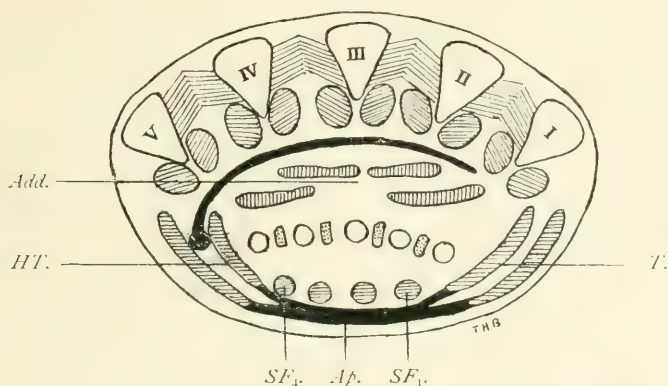


FIG. 19.—DIAGRAM SHOWING THE IDEAL PLAN ON WHICH THE INTRINSIC MUSCLES OF THE HAND AND FOOT ARE ARRANGED.

Ap., palmar or plantar aponeurosis; *SF₁*, *SF₄*, superficial short flexor muscles; *T.*, thenar marginal muscles; *HT.*, hypothenar marginal muscles; *Add.*, adductor layer; I-V, carpal or tarsal bones, with layer of deep short flexors, and intermetacarpal or intermetatarsal fibres.

of the ulnar nerve in the hand, or of the lateral plantar nerve in the foot, is a series of short deep flexors, two to each digit. If these are united proximally, each digit appears provided with a single muscle with two heads of insertion. *Fourth*, connected with these deep flexors, systems of interosseous fibres extend between the metacarpal or metatarsal bones. According to the account given by M^rMurich, these interosseous fibres constitute a separate and independent layer in lower forms. In higher forms, however, they would appear to be extensions from the deep flexors, because, for instance in man, the interosseous muscles at first lie volar to the metacarpus or metatarsus and subsequently extend dorsally between the bones. Out of the deep short flexors and the interosseous fibres the so-called interosseous muscles have been evolved, the slips becoming arranged in such a fashion that, in addition to their primary action as flexors, they come to move the digits to or from an axial line. The ideal hand thus reconstructed is represented in section in fig. 19. Under the head of the short muscles of the hand and foot the derivation of the adult arrangements from this ground plan will be considered.

VARIATIONS OF THE MUSCLES

The muscular system is extraordinarily variable. Apart from minor degrees of variation in the extent of attachment of the fleshy bellies and so forth, more profound departures from the normal are frequently met with in the form of accessory heads of origin or insertion, fission or fusion of fleshy bellies or tendons, interconnexions of various kinds and to various degrees. Again, muscles normally present may be absent. In one or two cases absence is almost as frequent as presence. Anomalous slips of all sorts appear in individual instances. Quite a large number of these abnormal muscles has been described, and as they are repeated in different subjects, some rarely, some more commonly, in the same form, they have received special names. Some occur so frequently that they almost have a title to be included within the limits of the normal.

Of all the organs the muscles seem the most plastic in development. While they develop on a constant general plan, the detail seems, as it were, less fixed. The muscular system is subject in a special degree to modifications in response to functional adaptation, and thus in comparative myology many cases of what is called *convergence* occur, *i.e.* the development of similar structures in forms quite unrelated genetically. Many variations in man are found to correspond to normal arrangements in lower animals. The term *atavistic* may be applied to *some* of these variations, but care must be exercised in using the term. We are not justified in describing a variety as an atavism unless there are clear grounds for believing that it existed in the human phylum, and has dropped out at some stage. There are variations which hark back to a primitive generalised arrangement which is common to all mammals, while there are others which appear to represent later intermediate stages in the evolution of the finished human muscles. Variations of the first category may find their parallels in any order of mammals, but it is a case of convergent development, and there is no question of genetic relationship. Varieties of the second class may be reminiscent of structural features seen in the more generalised primates, when they probably represent an early phase in the phylogeny of the human muscles, or in the higher apes only, when they may be considered as more recent modifications.

Certain muscles seem more stable than others, and it may be presumed that their characters have been fixed early in phylogeny, and have not since been subject to much functional adaptation. Other muscles seem in a state of unstable equilibrium, and on inquiry it is found that these belong to two classes. Some muscles, having lost their primary function, have become degenerate; others show features of adaptation recently acquired, and either peculiar to man, or shared with him by the higher apes only. Varieties in the latter class of muscles are often termed *progressive variations*, while variations indicating loss of function, recent or remote, with degeneration are termed *retrogressive variations*.

A vast literature of variations has accumulated, and special catalogues have been published by Macalister, Testut, and Le Double. The two volumes of Le Double's work may be referred to for a list of variations published before the year 1897. In the bibliographical appendix to this volume most of the more recent papers are included. The lists of varieties included in the text are only those which are of interest, either from their frequency or their morphological import.

DESCRIPTIVE MYOLOGY

THE MUSCLES OF THE HEAD AND NECK

THE muscles to be dealt with in this division combine the superficial or cutaneous musculature of the neck and face, the muscles of mastication, the orbital muscles, the constrictors and other muscles of the pharynx, and the muscles of the anterior region of the neck, including the extrinsic muscles of the tongue. The dorsal musculature of the neck being continuous with the deep muscles of the back, will be considered in a later section.

From the developmental and morphological points of view the muscles fall into two divisions: **I.** Muscles of the head divisible into three groups: (*a*) the orbital muscles developed from the dorsal mesoderm of the head; (*b*) somatic muscles developed from the mesoderm of the branchial arches, including the muscles of mastication from the mandibular arch, the facial musculature from the hyoid arch, and certain deep muscles of the same arch; (*c*) visceral muscles of the head region represented by the muscles of the pharynx and palate. **II.** Muscles of the trunk developed from the cervical myotomes and divisible into the following groups: (*a*) muscles on the front of the neck, or hypobranchial muscles; (*b*) deep muscles on the side of the neck, further divisible into (*a*) a lateral series, and (*β*) a medial series, according to their relation to the cervical nerve trunks. The sterno-mastoid and trapezius are branchial muscles by origin, but lie superficial to certain of the muscle groups indicated, and will be included with them.

THE CUTANEOUS MUSCLES OF THE HEAD

The muscles of this group or system lie immediately below the skin, and are attached at one extremity to bone or fascia, and at the other to the integument. The muscular fibres, as they pass to the skin, break up into very delicate fibrillæ, which end in extremely delicate tendinous fibrils, which form a feltwork in the cutis. They are all supplied by the seventh cranial nerve.

Phylogenetically they are probably derived from the subcutaneous extension of a muscle (interhyoideus) extending between the hyoid arches (Edgeworth). The sheet ultimately becomes divided into two parts known as the *platysma* and *sphincter colli*. The latter has, in man, disappeared from the neck, but is apparently still represented on the face, in part at least, by the sphincter muscles surrounding the facial orifices.

The facial muscles form a continuous sheet in lower primates. They are individualised to a much greater degree in man than in the higher apes, but even in man they are to some extent connected with one another by the interweaving of their marginal bundles. The muscles are arranged either concentrically round the orifices, or radially disposed to them.

The whole cutaneous musculature is developed from a single rudiment in the hyoid arch. In connexion with this the facial nerve ends in a tuft of diverging branches. From this centre the muscle sheet spreads in all directions, the nerve fibres following *pari passu* with muscle fibres, downwards over the neck, forwards over the face, and upwards over the vault of the skull. In early stages, according to the account given by Futamura, there are two layers of premuscle tissue—differing from one another in histological characters—in the facial part of the sheet, a deep layer which he identifies with the sphincter colli, and a superficial which he looks upon as the platysma. The deep layer gives origin to primitive sphincter arrangements round eye, nose, mouth, and ear. Except in the case of the mouth, these early sphincters disappear, and are replaced by new formations wrought out of the superficial or platysma sheet. This, while still in the premuscle stage,

extends over the vault, and is divided into two streams by the ear. Above the ear the occipital platysma and the facial platysma join and soon cover the whole vault with a continuous sheet of muscle—the fronto-occipital sheet. The occipital platysma becomes separated from the neck portion and, coincident with the expansion of the brain case in all its dimensions, certain portions of the continuous fronto-occipital sheet become separated by wide intervals in which the tissue suffers atrophy. The ear muscles and those round the eye are developed from the platysma sheet, as are also the nasal muscles and certain of those of the mouth. The sphincter colli layer survives in the orbicularis oris and some of the radiating muscles associated with it; others come from the platysma sheet.

The cervical extension of the sheet will be first considered. Thereafter the facial muscles proper will be taken in order, according as they are related to ear, eye, nose, and mouth.

M. Platysma Myoides (figs. 20, 21). The platysma is a thin muscular sheet extending over the front and side of the neck and lower portion of the side of the face, and placed superficial to the deep cervical fascia. It consists of pale coloured fibres which spring in thin bands from the subcutaneous tissue and skin over the upper part of the pectoral and deltoid muscles, and also by variable bundles along the dorsal border of the sheet from the cervical fascia. The fasciculi run almost parallel to one another and are directed upwards and medianwards, so that the two muscles, separated from one another above the sternum, converge and meet in the middle line in the suprahyoid region. The greater number of the fibres are attached to the outer surface of the mandible from the mental protuberance to the masseter. The innermost fibres mingle with those of the opposite platysma in front of the symphysis, and the most medial fibres of all cross from one side to the other, and are attached to the lower border of the mandible opposite the mental protuberance. Of the crossing fibres, those of the right side are generally superficial to those of the left. The outermost, or dorsal, bundles are prolonged upon the side of the face, and bend forwards to reach the angle of the mouth, where they are inserted, being prolonged to the skin of both the upper and lower lips, and interwoven and blended with the fibres of the triangularis (depressor anguli oris) and orbicularis muscles.

The muscle is supplied from the cervical branch of the facial nerve, and according to Eisler the nerve filaments enter along two lines; one of these lines runs from the angle of the mandible ventralwards, and the twigs of supply form a plexus with extended rhombic meshes; the second courses transversely through the muscle below the middle of the neck, and the twigs to the muscle come from the plexus formed by the anastomosis with the superficial cervical nerve, as well as from the first named plexus.

Varieties.—The platysma is a very variable muscle. Suppression of the whole sheet on one or both sides has been recorded. In rare cases the muscle does not extend over the lower part of the neck, but more frequently it exceeds its normal limits. It may extend further over the thorax, and sometimes it receives a slip from the clavicle. The two muscles may meet in the middle line not only in the suprahyoid region, but even down to the suprasternal notch.

The platysma may also extend higher up than usual over the face. In such cases bundles of fibres are found springing along the dorsal border of the muscle from the cervical fascia over the trapezius or sterno-mastoid, or even from the mastoid process. The muscle then covers the whole parotid region of the cheek. The fibres pass to the angle of the mouth, and radiate upwards to the zygomatic arch, and forwards as far as the orbicularis palpebrarum. Not infrequently a separate muscular slip is seen arising from the fascia over the upper part of the trapezius or the occipital bone, and ending in the fascia over the sterno-mastoid, or in the parotid fascia. This constitutes the superficial form of the *transverse nuchæ* (*occipitalis minor* of Santorini) which will be noticed again under the head of the auricular muscles.

Cases have been described of remarkable displacements of fasciculi of the platysma. A bundle of fibres may leave the medial border of one muscle, and arching over the median plane in the region of the suprasternal notch, descend along the medial border of the opposite muscle. A slip is sometimes observed arising from the fascia in the parotid region and running downwards over the angle of the jaw and risorius muscle towards the chin, where it may end in various ways. In one case described by Wood, the slip passed under the chin to join a similar slip from the opposite side. A transverse slip is sometimes seen detached from the lower part of the muscle,

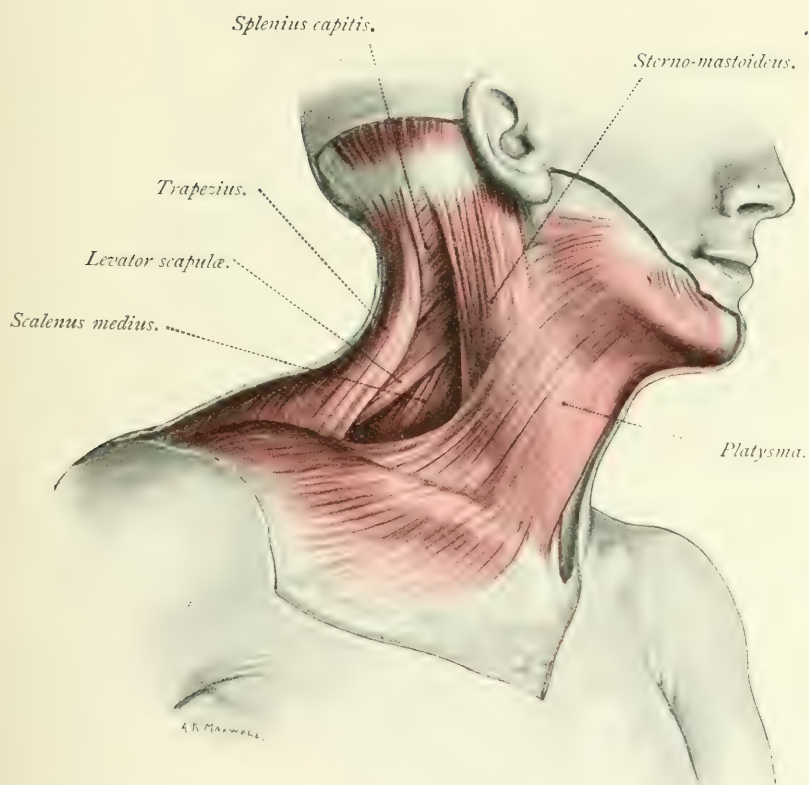


FIG. 20.—MUSCLES OF THE SIDE OF THE NECK AS SEEN IN A SUPERFICIAL DISSECTION.

and passing from the region of the sterno-clavicular joint lateralwards to end in the fascia and skin over the acromion (*preclavicularis subcutaneus* of Grüber). In very rare instances the lower part of the muscle has been seen resolved into detached bundles, the medial running upwards, the lateral transversely outwards.

The Auricular Group of Muscles.—This group includes the occipitalis and the true auricular muscles.

The **occipitalis** muscle (fig. 21), thin and flat, arises by short tendinous fibres from the lateral two-thirds, sometimes less, of the superior curved (nuchal) line on the occipital bone, and the mastoid portion of the temporal bone above the attachment of the sterno-mastoid muscle. The fleshy fasciculi, from 3 to 4 cm. in length, are directed upwards, and end in distinct tendinous fibres, which enter the epicranial aponeurosis.

The interval between the muscles of opposite sides is occupied by an extension of the aponeurosis. The muscular fibres are deep in colour and relatively coarse.

The **auricularis posterior** (fig. 21) is a small muscle which arises by short tendinous fibres from the mastoid portion of the temporal bone, and is inserted into a vertical ridge on the cartilage of the pinna at the back of the concha. The muscle usually consists of two or more separate fasciculi; and the tendon of insertion of short inner, and longer outer, fibres.

The **auricularis superior** (fig. 21), the largest of the three auricular muscles, has no bony attachment. Its tendinous fibres of origin are interwoven with those of the epicranial aponeurosis from the temporal part of which it arises. The muscular fasciculi are very delicate, and converge from a wide surface to be inserted by a compressed tendon into the anterior part of the helix, and into the eminence on the cranial aspect of the pinna corresponding to the fossa of the antehelix.

The **auricularis anterior** (fig. 21), scarcely separate from the preceding muscle, is pale and indistinct. It arises from the temporal prolongation of the epicranial aponeurosis, and passes backwards to the spine of the helix, on the medial aspect of which it is prolonged to the concha.

In a considerable number of cases a muscle named *auriculo-frontalis* or *superficial temporal* is present and intimately connected with the anterior auricular muscle. It varies greatly, but when fully developed it is placed between the frontalis, the superior auricular and anterior auricular muscles. It lies on the surface of the last named, separated from it by a thin, flat tendinous intersection which, according to Poirier, is constant and should be regarded as the origin of the anterior auricular muscle.

Varieties.—The occipitalis is primarily an ear muscle, but in man it is conjoined with the frontalis by the epicranial aponeurosis, and no longer acts upon the pinna. It has been seen united with the posterior auricular muscle, and fibres have been observed passing to the auricle independently. It varies in the degree to which it is developed; sometimes it extends to the median plane. On the other hand, its absence has been noted in a few cases. It is occasionally subdivided into slips. The three auricular muscles, rarely capable of voluntary action, represent the complex series of muscular slips which move the auricle in lower mammals. The posterior and anterior are subject to greater variation than the superior, but all vary somewhat in the extent of their development, the posterior more frequently by an increase in the number of the slips, the anterior by a diminution of the volume and distinctness of the fibres. The origin of the posterior muscle is sometimes carried backwards to a variable extent along the superior curved line of the occipital bone, or a second portion may arise from the occipital protuberance, the cervical fascia, or tendon of origin of the trapezius. The superior muscle may be in rare cases absent, or may be subdivided into slips, or into two layers. The anterior muscle is occasionally absent. Cruveilhier described as normal a deep slip passing from the zygomatic process to the outer surface of the tragus.

Certain anomalous or occasional muscles must be included in this group. The *auriculo-frontalis* or *superficial temporal* muscle has already been described. The *auricularis inferior* is a rare variety. It lies on the parotid fascia, from which it arises and passes to the base of the concha of the auricle.

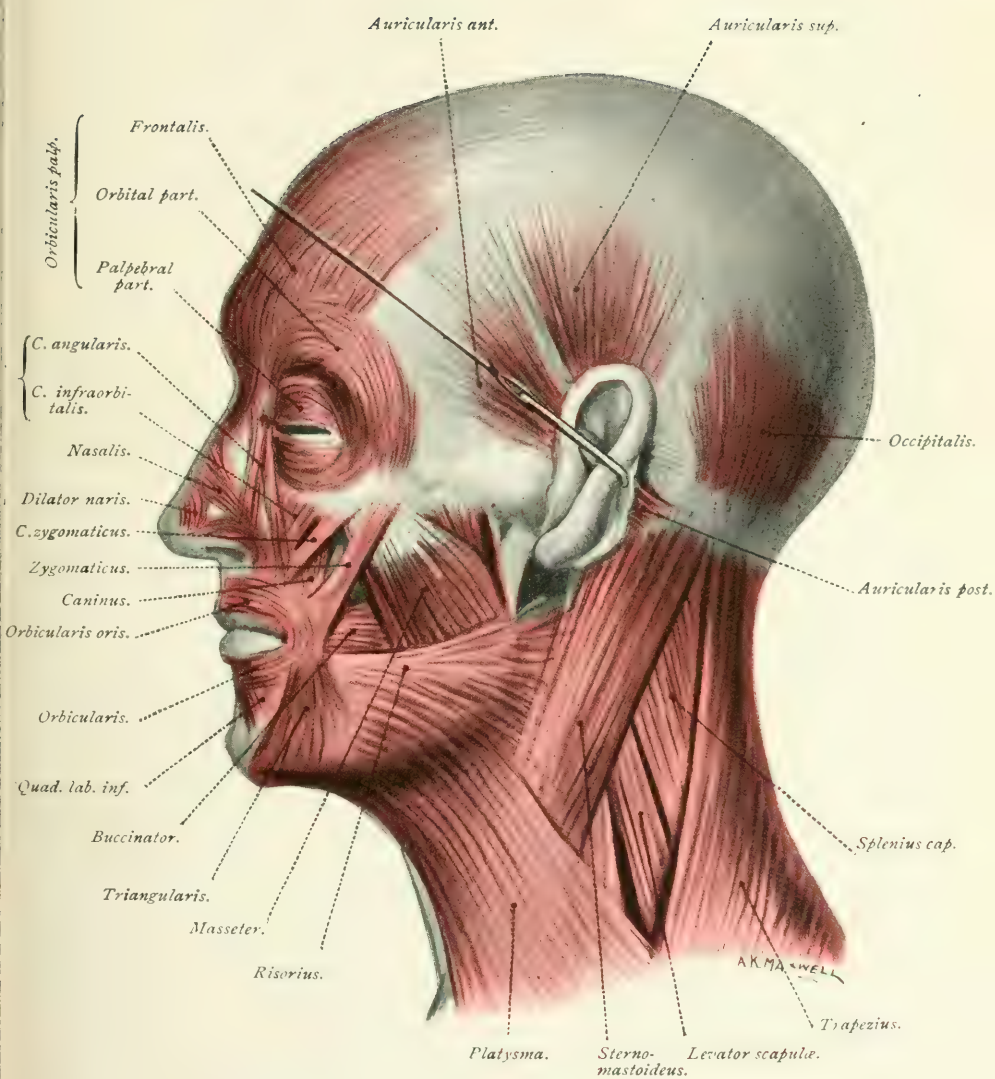


FIG. 21.—MUSCLES OF THE FACE AND SCALP—SUPERFICIAL DISSECTION.

The *transversus nuchæ* is a muscular slip, placed lateral to the occipital protuberance along the superior curved (nuchal) line, from the medial part of which it arises. It may be either superficial to the trapezius muscle or deep to it, and is attached at its lateral end to the lateral part of the curved line, to the border of the sterno-mastoid muscle, or to the posterior auricular muscle. In another form it may fuse with the fascia over the sterno-mastoid, or with the parotid fascia, and in part merge with the posterior auricular muscle. In yet another form it is directed downwards and ends in the cervical fascia, but in this case it is doubtful whether it comes into the category of the muscles supplied by the facial nerve. A remarkable compound muscle of rare occurrence may be mentioned here (*m. occipito-hyoideus*), consisting of a dorsal belly arising from the fascia in the occipital region which crosses the sterno-mastoid and is joined by a tendinous expansion to a ventral belly, which in turn is inserted into the hyoid bone with or without a slip to the stylo-pharyngeus. The first slip may be wanting and we have a *platysma-pharyngeus*. The first of these cases is to be explained by assuming a persistence of the early connexions between the superficial and deep portions of the muscle rudiment in the hyoid arch, which give rise to the platysma on the one hand and the posterior belly of the digastric and styloid-hyoid muscle on the other; the second by an early union of the sphincter colli with deep muscles in the region of the second and third branchial clefts.

Muscles Round the Opening of the Orbit.—The **frontalis** muscle (fig. 21), larger and of a paler colour than the occipitalis, occupies the forehead. A little below the level of the fronto-parietal suture the muscle is continuous along a convex border with the epicranial aponeurosis, while inferiorly the fibres terminate in the skin at the foot of the nose and along the whole length of the eyebrow. Laterally the fibres interlace with those of the orbicularis palpebrarum and corrugator supercilii, but medial to the orbicular muscle they are continued downwards and appear to be continuous with the pyramidalis nasi. The fibres are nearly vertical, running slightly medianwards as they descend. The margins of the right and left muscles are united in the middle line for some distance above the root of the nose, but are separated by an angular interval superiorly.

Varieties.—According to Eisler, the frontalis is not a simple muscle consisting of fibres passing the whole length of the belly, but is made up of a considerable number of alternating and overlapping bundles attached to extremely delicate tendinous intersections. The muscle is often credited with normal bony attachments round the supraorbital margin or to nasal bone or to neighbouring muscles—but these are admitted neither by Poirier nor Eisler. The muscle is sometimes thick and divided into single bundles. In one case noted by Macalister it was absent.

The **epicranial aponeurosis**¹ is a sheet of fibrous tissue which covers the vault of the skull without any interruption in the middle line, between the occipital, frontal, and superior auricular muscles of the two sides. The superficial surface is firmly bound to the skin by an abundant network of connective tissue, by the meshes of which the subcutaneous fat is divided into granules. The deep surface slides upon the subjacent pericranium, to which it is loosely attached by a delicate areolar tissue devoid of fat. The aponeurosis is regarded by some authors as representing the degenerated portion of the primitive fronto-occipital sheet of muscle. It may also be looked upon as the deep layer of the subcutaneous fascia, which has developed a tendinous or aponeurotic character, owing to the tensional stresses to which it has been exposed, especially to the pull of the muscles connected with it. It consists of a web of tendinous bundles contributed to it by the tendinous fibres of the several muscles attached to it, but it is not truly aponeurotic in every part. In the interval between the occipital muscles behind the vertex, it has more the character of an ordinary fascia, and on the sides of the skull below the temporal lines it largely loses its aponeurotic character, and is prolonged downwards between the frontalis and superior auricular muscle as a thin fascial membrane.

¹ The name *galea aponeurotica* is given to the aponeurosis in the B.N.A. from *galea*, a helmet, usually of leather.

The aponeurosis may be said to have three layers—superficial, middle, and deep, although, of course, any separation of these is purely artificial. The superficial layer, fascial in character, is continued over the outer face of the muscles and is fused with their perimysium. It is everywhere connected, as already stated, with the skin.

The deep layer is not confined any more than the superficial to the region of the aponeurosis, but is continued on to the deep surface of the muscles. Posteriorly it is attached with the occipitalis to the superior curved line; anteriorly it passes on the deep face of the frontalis to disappear in the tissue of the eyebrow and beneath the pyramidalis nasi; while laterally it follows the posterior and superior auricular muscles to the pinna. In front of the pinna, it is continued on the deep aspect of the auriculo-frontalis if it is present, or exposed in its absence, into the subcutaneous tissue of the cheek. The non-aponeurotic part of the membrane behind the vertex is fairly strong, and is continued behind into the subcutaneous tissue of the back of the neck, but has deep attachments to the external occipital protuberance and medial parts of the superior curved lines. The fibres are mainly transverse in direction.

The middle layer consists of the tendinous bundles connected with the muscles, the strongest being those connected with the occipitalis muscle. The great mass of the occipital fibres pass obliquely forwards and upwards, and a certain contingent, varying in different cases, crosses over the middle line in the region of the vertex, becoming interwoven with those of the opposite side.¹ The more laterally placed bundles are directly connected with the frontal part of the aponeurosis, and are interwoven with finer bundles of shorter fibres belonging to the frontalis muscle. The outermost, or anterior, fibres run more horizontally, and pass over or under the superior auricular muscle to join the upper part of the layer on the deep face of the frontalis, or end in a delicate tendinous network in the temporal region. The tendinous fibres of origin of the superior auricular muscle radiate in fan-like fashion into the aponeurosis, crossing those of the other systems. According to Eisler, there is a direct connexion with the skin, in the position of the infantile anterior fontanelle, of fibres coming both from the occipital and frontal parts of the aponeurosis.

M. Orbicularis Palpebrarum (Oculi) (fig. 21).—This is a thin elliptical muscle which surrounds the fissure between the eyelids and covers their surface, but also spreads for some distance beyond the orbital rim, upwards on the forehead, outwards on the temple, and downwards on the cheek. It consists of two portions which differ in their arrangement and action. The **palpebral** portion is that part which is contained in the eyelids. It is composed of thin pale fibres which arise from the upper and lower margins of the medial palpebral ligament, and sweep outwards, describing a slight curve, to be attached to a raphe formed by the much less well-developed lateral palpebral ligament. It is separated from the skin by a layer of loose areolar tissue devoid of fat; its deep surface rests on the tarsal plates and palpebral fascia. A somewhat thicker fasciculus which lies along the free margin of each lid is distinguished as the *ciliary* bundle.

The *medial palpebral ligament*, often described as the tendon of origin of the orbicularis, is a short white band, which is often obscured by the fibres of the muscle, but is rendered prominent by drawing the lids outwards. It is attached to the anterior lacrymal crest on the nasal process of the maxilla, and stretches outwards to the medial palpebral commissure, where it divides into two thin fibrous

¹ The crossing fibres sometimes form a definite band of some strength which actually produces a depression in the outer table of the skull behind the coronal suture area (D. McCallum Blair, *Four. of Anat.*, vol. lvi., 1922).

lamellæ, which diverge and end on the tarsal plates. One surface of the ligament is subcutaneous; the other crosses the lacrymal sac a little above the centre, and is closely adherent to it. A process is given off from the deep surface which passes on the posterior aspect of the sac to be attached to the posterior lacrymal crest on the lacrymal bone. It is not adherent to the sac. The *lateral palpebral ligament* is attached to the periosteum on the malar margin of the orbit, and to the tarsal plates in the same manner as the medial ligament. It is much weaker, however, and has not the cord-like consistency of the medial ligament. It is to a great extent concealed from the surface by the intercrossing of the muscular fibres from the upper and lower lids.

If the medial palpebral ligament be considered as the tendon of origin of this part of the orbicular muscle, then its fibres may be described as springing from the nasal process of the maxilla and the lacrymal sac. Certain of the marginal and deep fibres in both lids are described by Eisler as arising from the lacrymal bone behind the sac. These are, according to his account, to be distinguished from the *muscle of Horner*, or, as he terms it, the *pars lacrimalis* of the orbicularis.

The *tensor tarsi* (*musc. sacci lacrimalis*, *Horner*) is by some considered to be an independent muscle; by others it is regarded as only a deep origin of the palpebral part of the orbicularis. It consists of a thin layer of muscle which springs from the posterior lacrymal crest and surface of the lacrymal bone behind the sac; passing outwards and forwards, it divides into two slips, which are continued behind the lacrymal canals, surround their ampullæ, and merge in the ciliary bundle of the orbicularis.

The peripheral or **orbital portion** of the muscle is larger, stronger, and of a deeper colour. It forms a broad band, which lies over the frontal bone and corrugator supercilii above, over the zygomatic bone laterally, and the maxillary bone and origins of the levator muscles of the lip and ala of the nose below. Its fasciculi are arranged concentrically, appearing almost as rings where orbital and palpebral portions merge, but as the margin is approached they describe ellipses which gradually widen. On closer examination and dissection it is found that the individual bundles are not continued the whole way round, but are crossed and interwoven on the outer part of the circumference where there is no bony attachment, while many sweep out of the circle to the skin and into neighbouring muscles. The muscle may therefore be described, like the palpebral part, as consisting of upper and lower portions, or systems of fasciculi. The upper portion arises from the inner part of the medial palpebral ligament, the whole length of the nasal process of the maxilla, and medial portion of the orbital arch of the frontal bone. A certain proportion of the fasciculi bend round and run in the orbital band, but many, both of the superficial and deep fibres, leave this and extend into the eyebrow, where they are interwoven with the frontalis and corrugator supercilii muscles, and into the subcutaneous tissue and skin. This portion has been termed the *depressor supercilii*. The inferior fibres arise from the lower aspect of the palpebral ligament, from the anterior lacrymal crest, and the orbital margin for a considerable distance along the infraorbital rim. Many of the fibres curve round in the orbital band, and join the corresponding curving fasciculi of the upper portion; others leave the band and enter the skin; other fibres diverge, and pass to the skin over the quadratus labii superioris. From the lateral margin of the orbicularis, above and laterally, fasciculi diverge into the lower end of the eyebrow on to the temporal extension of the epicranial aponeurosis, while below and laterally other fibres leave the band and sweep with the zygomatic muscles to the skin of the cheek. These slips were described separately by Henle under the name of the *malaris* muscle.

The **M. corrugator supercilii** is a small, deeply coloured, and relatively coarsely fasciculated muscle, placed at the medial end of the eyebrow, under cover of the frontalis and orbicularis muscles. It arises from the medial end of the supraciliary ridge of the frontal bone, where there is often a distinct mark indicating the attachment of the muscle. The fasciculi extend outwards and upwards, diverging somewhat, and end about the middle of the orbital arch by passing between the bundles of the orbicularis and frontalis, to be inserted into the deep surface of the skin of the eyebrow.

The **M. pyramidalis nasi** (Procerus) (fig. 21, unlabelled, however), although placed over the nasal bone, belongs by its action to this group of muscles. It arises from the nasal bone, and from a tendinous expansion common to it and the compressor naris muscle, or even from the lateral cartilage of the nose by means of a membrane beneath the compressor muscle. It is inserted into the skin between the eyebrows, and its fibres decussate with those of the frontalis. There is no demarcation superficially between the frontal muscle and the pyramidalis which appears as a downward prolongation of the frontalis fibres. The marginal bundles of fibres may intercross with those of the orbicularis palpebrarum. Some deep fibres end in the tendinous expansion on the deep face of the frontalis.

Varieties.—The pyramidalis may be absent on one side or on both, and may be better developed on one side than the other. The attachments vary considerably. It is certainly to be regarded as a distinct muscular unit, but it is very seldom that it is sharply separated from the frontalis. The two muscles may be continuous over the bridge of the nose.

Muscles of the Nose.—Under this head are included the compressor naris and depressor alæ nasi; a slip from

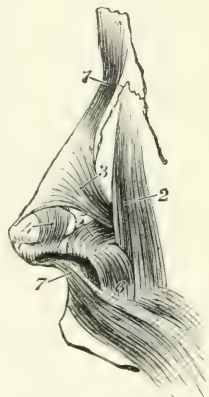


FIG. 22.—MUSCLES OF THE SIDE OF THE NOSE AND UPPER LIP.
(Allen Thomson, after Arnold.) $\frac{2}{3}$

1, M. pyramidalis nasi (procerus); 2, M. quadratus labii superioris, angular head; 3, M. nasalis, pars transversa; 4, M. levator proprius alæ nasi anterior; 5, M. levator proprius alæ nasi posterior; 6, M. nasalis, pars alaris; 7, Septal origin of M. orbicularis oris.

the angular head of the quadratus labii superioris (levator labii superioris alæque nasi); and certain small muscles in the wing of the nose.

The B.N.A., following Henle and Gegenbaur, combines the compressor and depressor alæ nasi into one muscle, the *m. nasalis*, with two parts *pars transversa* and *pars alaris*. There is much to be said for this; as the two are certainly continuous at their origin, and rather to be regarded as parts of one sheet, which arises from the facial surface of the maxilla by the side of the nasal aperture, and extends downwards to the incisive fossa.

M. Nasalis.—The **pars transversa** or **compressor naris** (figs. 21, 22) consists of the long, lateral, and upper fibres of the common sheet. Surrounding the mobile portion of the nose along the line of the alar groove, it expands and ends in a thin aponeurosis, which becomes blended in the middle line of the nose with that of the opposite side, and above with the pyramidalis muscle. The aponeurosis is closely attached to the skin, and only connected to the subjacent cartilages by loose areolar tissue. The **pars alaris** or **depressor alæ nasi** comprises the short lower fibres, which find attachment to the skin of the back of the ala, the lower part of the septum of the nose, and even the medial crus of the cartilage of the aperture, where it descends in the septum. Between the two systems of fibres one can generally determine the existence of intermediate bundles which turn

into the ala to be attached to the skin. The slip from the quadratus labii superioris will be described along with the muscles of the mouth. It conceals the muscle just described at its origin.

In the ale of the nose certain muscular slips may be defined which appear to act as elevators of the ale, or dilators of the nasal apertures (fig. 22). They are difficult to demonstrate, and seem to vary in their development. They can, however, generally be detected by removing the skin from the side of the nose from above towards the ala, and then reflecting the nasalis muscle. If the connective tissue be now carefully cleaned away, bundles of fibres are seen passing into the ala, in two sets, one arising from the edge of the nasal aperture and from the membrane and minor cartilages behind, the other from the cartilage of the aperture, or even the edge of the lateral cartilage in front. If these fibres be followed into the ala by carefully reflecting the skin, it will be seen that they end in the deep layer of the cutis. In a typical instance they do not extend beyond the posterior half or so of the nasal aperture. The posterior and anterior systems of fibres may be more or less separated, and were named *levator alae nasi posterior* and *anterior* by Arnold; *dilatores nasi posterior* and *anterior* by Theile.

Varieties.—Under the dilator muscle described in the preceding paragraph, a minute muscle is frequently to be identified named *m. apicus nasi* by Luschka, and *compressor narium minor* by Arnold. It consists of a few bundles arising from the lateral crus of the cartilage of the aperture, and passing horizontally forward to end in the anterior part of the nasal margin, on the cartilage at the junction of the two crura and its apical part. The *musculus anomalus* of Albinus is a longitudinal muscular slip attached to the maxilla by both extremities. It arises under cover of the common elevator of the lip and nose, from the nasal process of the maxilla under the muscle, and ends below in a variety of ways, either by a single slip or a number of slips. The commonest termination is by a slip attached to the maxilla just medial to the canine fossa, and it runs in the line of the naso-labial furrow.

Muscles of the Lips and Mouth.—The orifice of the mouth is surrounded by a sphincter muscle named orbicularis oris, and with this are conjoined the radiating fasciculi of a number of muscles which converge on the aperture from above, from below, and from the sides. The fasciculi from above and below enter the lips, are intermingled with the transverse fibres, and end in the skin. The fibres converging from the sides on the angles of the mouth are either continued directly into the orbicularis, or continuity is established by very fine tendinous intersections. At the angle a decussation of fasciculi occurs, and gives rise to a mass of muscle which may be felt during life as a node between the skin and mucous membrane, a little external to the commissure of the lips. In the lips the fibres are mainly inserted on the skin, but also into the mucous membrane, and these deeper connexions are especially important in the region of the angle of the mouth.

In describing these muscles the Basle nomenclature will be accepted without reserve. The muscles are so variously named in the text-books in different languages, that it is not easy often to identify the particular muscle referred to. It seems desirable that a common system of names be adopted. The muscles are arranged and named as follows: (1)*muscles converging on the angle of the mouth, the risorius, the triangularis labii inferioris, the zygomaticus, and on a deeper plane the caninus; (2) elevator muscles passing to the upper lip, three in number, and grouped under the name of quadratus labii superioris; (3) a depressor muscle to the lower lip, quadratus labii inferioris; (4) the buccinator, and orbicularis oris, and (5) levator menti muscle.

M. Risorius (figs. 20, 21).—This muscle consists of some very thin fasciculi, which arise from the fascia over the masseter or on the parotid gland, or even in

some cases further back. It extends transversely medianwards in the fat of the cheek to reach the angle of the mouth, where it is inserted into the skin and perhaps also the mucous membrane by some fibres running between the bundles of the triangularis.

Varieties.—The muscle varies in extent, and is sometimes absent altogether. It has been seen arising from the fascia over the sterno-mastoid, or the mastoid process, the outer ear or zygomatic process. It has also been found double or even triple.

M. Triangularis (fig. 21).—This muscle arises by a broad origin from the oblique line on the mandible. The fibres which are relatively coarse converge, as the name indicates, on a narrow bundle at the angle of the mouth. Here some of them are inserted into the skin; others pass into the upper lip, where they end in the skin or merge with the orbicularis oris. The deeper fibres decussate in the node with those of the elevator of the angle of the mouth (*caninus*). The muscle is superficially placed, being covered by skin and fat only. It overlaps the *quadratus labii inferioris* and part of the *buccinator*.

Varieties.—Continuous with the triangularis or detached from it a small band of muscular fibres is sometimes found extending medianwards below the chin to be continuous with the corresponding part of the opposite muscle, thus forming a small unpaired muscle known as the *transversus menti*. The triangularis may be subdivided into separate slips; a deep part below the *quadratus* of the lower lip has been described.

M. Zygomaticus (fig. 21).—This muscle arises from a slight furrow on the zygomatic bone just in front of the zygomatic suture. It extends downwards and forwards to the angle of the mouth, and is generally divided near its insertion into two slips by the *caninus* muscle. The superficial fibres end in the skin of the lateral part of the upper lip; the deeper fibres go to the mucous membrane of the upper lip. Some fibres are continued through the decussation into the orbicularis of the lower lip and the mucous membrane below the angle of the mouth.

Varieties.—The muscle may be absent. It is often divided into slips, and subdivision at the insertion is described as normal by many. It is specially large in the negro. Sometimes it extends backwards on the zygomatic arch, or upwards on the temporal fascia. It may receive slips from the fascia over the masseter and *buccinator* muscles. It may be joined to the zygomatic slips of the elevator of the upper lip, or receive a fasciculus from the orbicularis palpebrarum.

M. Caninus (*levator anguli oris*) (figs. 21, 23).—The *caninus*, so named from its attachments in the canine fossa, lies on a deeper plane than the preceding muscles. At its origin it is covered by the *quadratus labii superioris*, being separated from it by the infraorbital vessels and nerve plexus. It is overlapped by the zygomatic muscle, and only at the angle of the mouth comes to lie under the skin. It arises in the canine fossa immediately below the infraorbital foramen, and inclines downwards and slightly outwards to the angle of the mouth. Here some of its fibres end in the skin below the angle of the mouth; but the greater number decussate with bundles of the other muscles going to the angle of the mouth, and are blended with the orbicularis of the lower lip. Some bundles reach the mucous membrane of the vestibulum oris below the angle of the mouth.

Varieties.—The muscle may be divided into separate slips; it may extend medianwards and come in contact with the superior incisive muscle; aberrant bundles may connect it superficially with the nasalis, or pass to be attached to the fronto-nasal process.

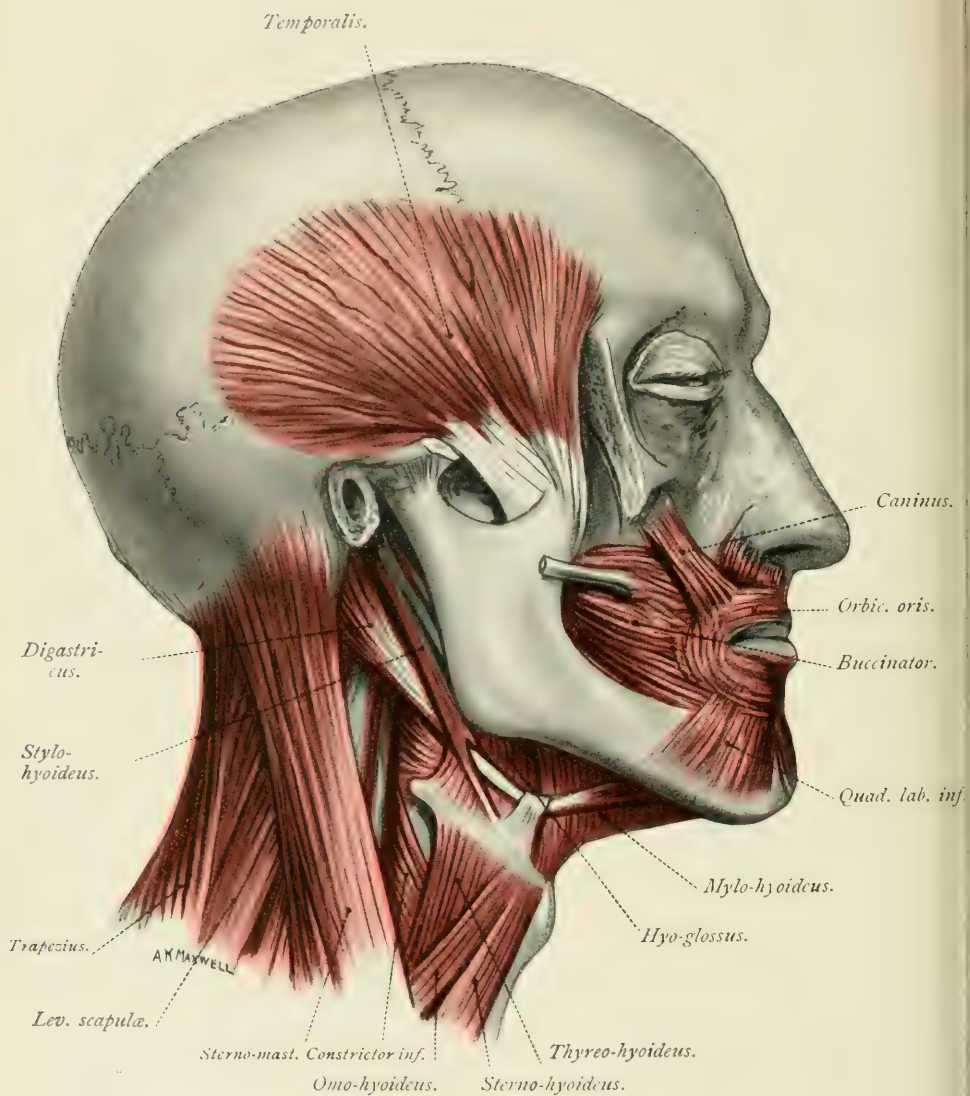


FIG. 23.—MUSCLES OF THE FACE, DEEP DISSECTION, WITH M. TEMPORALIS AND MUSCLES OF NECK.

M. Quadratus Labii Superioris (fig. 21).—This muscle consists of three separate slips or heads—zygomatic, infraorbital, and angular.

In the former edition of this work, the practice of Albinus and Santorini was followed, and three separate elevator muscles were described passing to the upper lip. In the B.N.A. the description of Henle has been adopted, and the three slips are considered as the heads of a single elevator named the quadratus labii superioris. Although it is true that each of the slips is individualised as far as nerve supply is concerned, and therefore morphologically distinct, they are frequently joined into a continuous sheet, and they are always merged at their insertion. On the other hand, subdivision of the middle and lateral heads occurs, so that a more complex arrangement of slips may arise.

The **lateral** or **zygomatic** head arises from the anterior and inferior part of the zygomatic bone. It inclines medially, and ends by joining the lateral border of the middle head, and is prolonged with it into the upper lip. It is frequently absent, and is sometimes reinforced or replaced by a fasciculus from the orbicularis palpebrarum. It is sometimes fused with the zygomaticus, and its origin may extend upwards to the temporal fascia. It may be united to the outer fibres of the frontalis (Eustachius).

The **middle** or **infraorbital** head arises from the maxilla above the infraorbital foramen and adjoining surface of the zygomatic bone. It inclines downwards and medially, is closely connected with the medial head along its inner margin, and is inserted into the skin of the ala of the nose along its posterior border, and into the skin of the upper lip in nearly its whole extent. It is covered at its origin by the orbicularis palpebrarum, and itself covers the caninus, from which it is separated by the infraorbital vessels and nerve. Its medial portion inferiorly passes below the fibres of the medial head, and when strongly developed it is overlapped laterally and medially by the lateral and medial heads.

The **medial** or **angular** head lies along the side of the nose. It arises by a pointed origin from the fronto-nasal process of the maxilla close to the medial palpebral ligament. It is resolved below into a fasciculus attached to the skin of the wing of the nose at its upper and back part, and into bundles which pass to the skin of the upper lip. It is covered at its origin by the orbicularis palpebrarum, which may give it reinforcing fibres, and it may rise higher than usual and become connected with the frontalis muscle. It is sometimes interrupted below by bundles of the transverse part of the nasalis muscle taking a superficial course.

M. Quadratus Labii Inferioris (figs. 21, 23).—The quadratus of the lower lip arises from the mandible by a line of attachment extending from near the symphysis to a little beyond the mental foramen. Thence it ascends with a medial inclination to the lower lip into the skin of which it is inserted, the medial fibres intercrossing with those of the opposite muscle. Deep fibres merge with the orbicularis, and some pass between its fibres to reach the mucous membrane.

Varieties.—It has been seen divided into two bundles. It is generally connected more or less with the platysma, receiving a considerable number of fibres from it. In lower mammals the sphincter colli is continued directly to the lower lip, without any interruption by attachment to the mandible. In the lower primates there is a partial mandibular attachment, and a portion of the sheet begins to be separated as a quadratus or depressor labii inferioris. The connexions with the platysma are therefore to be looked upon as representing the original continuity of the muscle with the cutaneous muscle of the neck.

M. Buccinator (figs. 21, 23, 38, p. 80).—The buccinator muscle consists of a flat, and thin, but strong set of fibres in contact with the mucous membrane, and forming a considerable part of the wall of the mouth. It is attached by its upper and lower margins to the outer surface of the alveolar process of the maxilla and of

the mandible respectively, opposite the molar teeth. Between these two origins it is attached behind to the *pterygo-mandibular ligament or raphe*, a narrow band of tendinous fibres which stretches from the hamular process of the medial pterygoid plate to the mylohyoid ridge of the mandible close to the last molar tooth, and is interposed between the buccinator muscle and the superior constrictor of the pharynx. From these parts the fibres of the muscle are directed forwards, and converge towards the angle of the mouth, the maxillary fibres descending and the mandibular fibres rising as they sweep to the angle. The middle fibres are mainly horizontal, but the lower bundles curve downwards in their course and cover over the mandibular bundles. In the last edition of this work it was stated that the higher and lower bundles of muscle fibres are continued into the upper and lower lips, to form the deep part of the orbicularis oris. Recent accounts, more especially that of Eisler, show, however, that while some superficial bundles pass over to be blended by very delicate tendinous intersections with the orbicular muscle, the greater part of the buccinator fibres are inserted into the mucous membrane along a vertical line above and below the angle of the mouth; in other words, the muscle fibres described as being continued into the lips suffer interruption at these points. Fibres near the middle of the muscle cross one another and are continued into the marginal part of the orbicularis, those from above passing into the lower lip, those from below into the upper one.

Relations.—The buccinator is covered and supported by a fascia, which is closely adherent to the muscle fibres. The muscle is overlapped by the triangularis, by the upper fibres of the platysma, in part by the masseter and zygomatic muscles. From these it is separated by a quantity of fat (buccal pad), embedded in which are the facial vessels and buccal branches of the facial and trigeminal nerves. Opposite the second molar tooth of the upper jaw, the duct of the parotid gland passes between the bundles of the muscle.

M. Orbicularis Oris (figs. 21, 23).—The orbicular muscle of the mouth is an elliptical sheet of considerable thickness making the foundation of the lips. Above it reaches to the base of the nose, below to the groove which separates the lip from the chin. The part of the muscle in the red margin of the lips consists of rather finer fibres, but is not distinctly separated from the peripheral portion of the sheet. A marginal seam is partially marked off near the free edges of the lips. The muscle is composed of arched transverse bundles of fibres in each lip passing from the middle line to the angles of the mouth. With these are interwoven (1) fibres which enter the lips at the angles; (2) fibres which enter the lips from above or below from the elevators and depressors; and (3) delicate antero-posterior fibres, only to be detected in microscopic sections, which extend from skin to mucous membrane.

There is no general consensus of opinion regarding the arrangement of the fibres in the orbicularis. The tracing of the fibres by dissection is extremely difficult, and the question still at issue is the extent to which fibres of extrinsic origin share in the composition of the sphincter. The muscle is developed from the deep layer of premuscle tissue on the face and the primitive sphincter, which, unlike those round nose, eye, and ear, persists. It takes form before the radiating bundles are wrought out of the sheet. The definitive caninus, zygomaticus (?), triangularis labii inferioris, with the risorius as an offshoot from it, and the buccinator are developed out of the deep layer. Most of the elevator muscles, the quadratus labii inferioris and the levator menti, are described as derivatives of the platysma sheet, which secondarily usurps the place of most of the more primitive formations (Futamura). So far as developmental data go, the orbicularis appears to be a separate and persisting formation. The following account is based on descriptions given by Charpy, Virchow, and especially Eisler, who gives a wealth of detail.

In each lip there are separate systems of fibres, extending from the middle line to the angles of the mouth (fig. 24). In both lips the superficial fibres are

closely attached to the skin in the median plane by fine tendinous bundles which form a close feltwork. Some fibres end on the same side, but the greater number decussate with those of the opposite side and cross the middle line. The deep

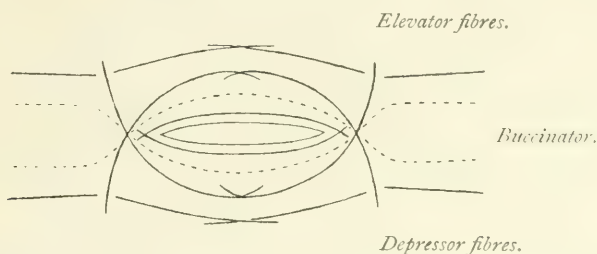


FIG. 24.—SCHEME OF THE FIBRES CONSTITUTING THE ORBICULARIS ORIS MUSCLE.

The naso-labialis and incisive slips have not been represented.

fibres also cross the middle line, some for a considerable distance, and are unattached to the mucous membrane. In the upper lip the decussation extends to the nasal septum, the uppermost of the superficial fibres, which form a more or less separate bundle (*M. naso-labialis*), reaching the back of the nostril and the septum below the medial crus of the cartilage of the aperture. In the lower lip the crossing fibres are mingled with decussating fibres of the quadratus, and are inseparable from those of the levator menti muscles. The transverse bundles of orbicular fibres extend outwards to the angle of the mouth, and there end mainly on the mucous membrane above and below the angle. Some are attached to the skin. The innermost fibres mostly cross at the angle, and are attached to the mucous membrane of the other lip. It is only these fibres going to the angle which are closely interwoven with fibres of the radiating muscles entering the lips at the angle, and a blending of the two systems occurs by interdigitation of fibres, which are bound together by delicate tendinous intersections and perimysium.

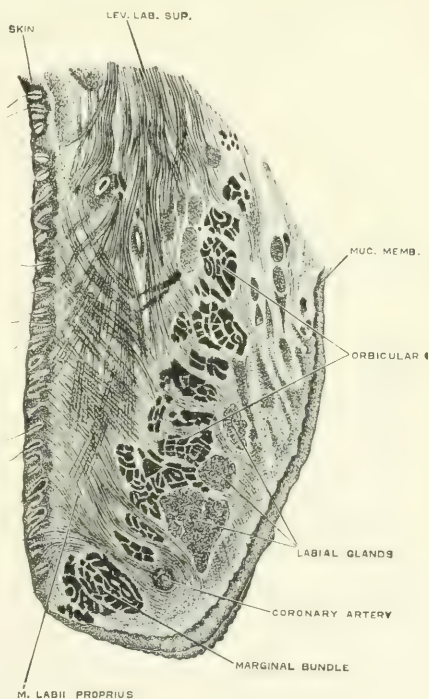


FIG. 25.—SAGITTAL SECTION OF UPPER LIP OF INFANT, A LITTLE TO ONE SIDE OF THE MEDIAN PLANE. (Aeby.)

In the marginal part of each lip (fig. 25), a special set of fine fibres, more developed in the infant than the adult, are seen in sections of the lips reaching from skin to mucous membrane. The system has received various names—*M. suctionis* (Luschka), *M. compressor labii* (Klein), *M. labii proprius* (Krause), *M. cutaneo-mucosus* (Bovero).

Two reinforcing systems of fibres detached from the orbicularis muscle are found in both the upper and lower lips, and named the incisive muscles.

The *M. incisivus inferior* is the stronger of the two. Its fibres arise from the incisive fossa of the mandible, and passing outwards are joined to the orbicular fibres and inserted with them at the angle of the mouth. It is intimately connected with the lowermost fibres of the buccinator.

The *M. incisivus superior*, thin and weak, arises from the incisive fossa of the maxilla, and arches laterally in the upper part of the lip to be inserted with the orbicular fibres at the angle of the mouth.

M. Levator Menti, or M. Mentalis.—This muscle is a short but strong bundle arising from the incisive fossa of the mandible by a narrow head. Expanding as it extends downwards and slightly forwards between the two quadratus muscles, it is inserted into the integument of the chin.

The *anomalous menti* is an almost constant muscular bundle which is attached to bone at both ends, and lies beneath the elevator of the chin. It is triangular in shape, with its base attached to the mental tubercle and its apex directed upwards fixed to the mandible.

Action of the Muscles of Scalp and Face.—The three small muscles of the auricle are not, in the majority of persons, under the control of the will. According to their position they are competent to draw the pinna backwards, upwards, and forwards respectively. The occipital muscles support the scalp behind, and tend to draw it backwards. By pulling on the epicranial aponeurosis, they provide a *point d'appui* for the frontal muscles. If they act alternately with the frontal muscles, the scalp is moved backwards and forwards. In the majority of persons this combined action of the muscles is only under control to a limited degree. The action of the frontal muscles in elevating the eyebrows will be noted later.

The complicated system of facial muscles, as already noted, has been evolved out of a primitive set of sphincter muscles placed round the orifices. The sphincter arrangement round the mouth has been developed to a high degree, and so has that round the orbital openings. The muscles of the nose have retrogressed, the only obvious movement remaining being the opening up of the nostrils by the elevation of the alæ. It was explained on p. 7 that a sphincter muscle which closes an orifice is necessarily associated with systems of radiating fibres to act as antagonists to the circular constricting fibres, and that this combination is to be seen both round the mouth and palpebral fissures. In the human subject the reason for the great development and the unusual degree of individualisation of the muscles is that they are intimately connected with the expression of the emotions. By the tonic contraction of the muscles and the pull of their fibres in different directions, certain lines and furrows are produced on the face. By the modification of these and by the displacement of parts, the muscles in actively contracting produce alterations in the facial mask which reflect changes in mental states.

Muscles of the Eyelids and Eyebrows.—The eyelids are brought together gently, as in sleep, by the palpebral part of the orbicularis. The upper lid moves much more freely than the lower, and its arched margin is brought into a horizontal position in contact with that of the lower eyelid, which is almost immobile. In closing the lids, as in winking, the internal tarsal ligament is carried forwards, and with it the wall of the lacrymal sac. In this way the sac is dilated and sucks in the tears. Forcible closure of the lids is effected by the co-operation of the orbital part of the muscle. The skin all round the orbit is drawn up so that the lids are firmly pressed together, while at the same time they are carried somewhat inwards towards the fixed part of the muscle. Thus the eyebrow is depressed and the skin of the forehead stretched by the contraction of the upper part of the muscle; the cheek is raised by the lower part, and the lower eyelid pushed upwards and inwards; while the lateral part pulls and stretches the skin of the temple, and gives rise to a series of radiating wrinkles outside the eye. The *tensor tarsi* muscle, according to one view, contracts simultaneously with the orbicularis and draws backwards the *puncta lacrymalia*, disposing them more favourably for the admission of the tears. But it appears more probable that it alternates in its action with the orbicularis, drawing back the internal palpebral ligament and compressing the lacrymal sac so as to propel the tears along the naso-lacrymal duct into the nose.

The two *frontal* muscles elevate the eyebrows, and at the same time the forehead is thrown into transverse wrinkles, which arch over each eyebrow and meet medially in short folds curving in the opposite direction. They are the antagonists of the orbicular muscles, and are themselves antagonised by the *pyramidalis nasi*. They are brought into action along with the levator palpebræ superioris muscles, when there is some difficulty of vision in connexion with distance or indistinctness, as if to throw more light into the eyes. A slight action suggests attention; a stronger action expresses surprise. The *pyramidalis* draws down the skin of the forehead, causing wrinkles across the root of the nose. It comes into action with the corrugator and the orbicularis when the eyes suffer from a glare. The depression of the skin between the eyebrows produces a

disagreeable and hard morose expression. Darwin pointed out that it was less under control of the will than the other muscles. The *corrugator* muscle draws the skin of the forehead downwards and medially, producing a projection and depression of the inner end of the eyebrow which is approached to its fellow, while longitudinal furrows are developed at the medial end of each. Primarily a protective muscle to the eye, it is brought into action when there is too much light, in concentration of vision in some delicate action, and in the absence of physical cause it is expressive of mental difficulty, or concentration on some difficulty. Called into action by some disagreeable impression, physical or mental, its contraction is expressive of a state of irritability, and when associated with the *pyramidalis* it produces the frowning brows of anger and threat.

Muscles of the Nose.—The transverse part of the nasal muscle acting from below depresses the cartilaginous part of the nose, while the alar portion compresses the nares together. The other small muscles lift the alæ and open the nostrils. They can be seen contracting spontaneously in dyspnoea, but not perceptibly in ordinary respiration.

Muscles of the Lips.—As in the case of the eyelids, the lips are drawn lightly together by the more marginal portions of the *orbicular* muscle, while the deeper and peripheral parts acting with the *buccinators* close the cleft between the lips and press them against the teeth. Acting more energetically the *orbicularis* narrows the mouth, while the incisive muscles adducting the angles draw the commissures together, at the same time everting the lips. The *levator menti* muscles co-operate by drawing up the skin of the chin and protruding the lower lip. The *buccinators* are the antagonists of the *orbicularis* and incisive muscles. The two muscles support the angles and lateral parts of the lips in the contraction of the *orbicular* fibres, and tend to elongate the oral aperture. When the mouth is filled with food the *buccinators* flatten the cheeks during mastication and keep the food between the teeth. If the cheeks are distended with air and the lips pressed together, the muscles regulate the forced expulsion of the air. If the mouth is empty the *buccinators*, acting while the *orbicularis* and the incisive muscles firmly close and protrude the lips, cave the cheeks inwards. It is in this way that they perform the action of suction.

The *risorius* draws the angle lateralwards, and so elongates the oral cleft. The zygomatic muscle draws the angle upwards and outwards, altering the shape of the naso-labial furrow, pushing up the tissues of the cheek and slightly raising the lower eyelid. It is the muscle chiefly concerned in the facial expression associated with mirth, the *risorius* acting with it. The *quadratus labii superioris* by its three slips raises the upper lip, and with it the ala of the nose, so as to uncover the canine and incisor teeth. Their action is expressive of ill humour or disdain; they are concerned in the sneer, and also come into operation in weeping. The *caninus* raises the angle upwards and medially, and lifts the lower lip slightly.

The *quadratus labii inferioris* depresses the lip, and the fibres being oblique towards the middle line, also stretches it transversely. The *levator menti* has the opposite effect. By raising the chin the lower lip is pushed upwards and forwards, and forcibly protruded. It carries the upper lip with it if the lips are kept in contact. Its action is expressive of a haughty humour and disdain, so that it has been called the *musculus superbus*. The *triangularis* carries the angle of the mouth downwards and somewhat outwards; it arches the upper lip and slightly depresses it. In consequence of its action the naso-labial furrow is drawn out and straightened. Its action is expressive of mental depression and grief. It is a factor in producing all the more complicated facial expressions which indicate a sombre or morose humour. The *platysma myoides* raises the skin of the neck and shoulder and draws the angle of the mouth forcibly downwards and outwards. At the same time it carries the skin forwards and reduces the angle between the chin and neck. The bands of muscle of which it is built up stand out under the skin as prominent cords in powerful contraction with the jaw fixed. The muscle is brought into action in swallowing, and is called into play in fear or sudden terror.

THE MUSCLES OF MASTICATION

This group of muscles includes the temporal, masseter, and the two pterygoid muscles. These muscles are all supplied by the mandibular division of the fifth nerve, and are developed from the mesoderm of the mandibular arch. The mylo-hyoid and the anterior belly of the digastric muscle should be included in the group if nerve supply be alone taken into account. But from the developmental point of view it is not certainly known whether the mylo-hyoid muscle is an offshoot from the same rudiment as gives rise to the other muscles, while it is

believed by some that the anterior belly of the digastric has its origin in the hyoid arch, and that the innervation from the fifth nerve is secondary and acquired.

The descriptive accounts which we possess of the development of the main masticatory muscles show that there is in the first instance a common premuscle mass for the whole series. This mass makes its appearance in the tissue of the mandibular arch round the terminal branches of the mandibular nerve. As the rudiment of the membranous mandible takes form in the arch, the muscular elements lie in close relation to it and are at no time attached to Meckel's cartilage. The common mass acquires a Y-shape. The stem of the Y, directed upwards, gives origin to the temporal muscle, while its limbs embrace the developing coronoid process, and are differentiated respectively into the masseter muscle on the outer face of the mandible, and the two pterygoids on its inner face. The pterygoid mass is subdivided into two parts by the intervention of the cartilage of Meckel and the mandibular nerve. The mylo-hyoid muscle is probably derived from the lower edge of the primitive common rudiment.

The connective tissue covering the outer face of the temporal and masseter muscles gives rise to the well-marked fasciæ named after these muscles, but the deeper portion of the investing tissue remains of looser texture, and forms less well-defined fascial lamellæ.

Fasciæ.—The **Temporal Fascia** is a fairly dense white shining membrane which covers the temporal muscle above the zygomatic arch. It is limited in its extent to the temporal fossa, being attached along the temporal crest on the frontal bone and the lower of the two lines on the parietal bone as well as the space between this and the upper crest when it exists, and below to the zygoma. Immediately above the arch it is separated from the muscle by a fat-filled interval. In the lower part of its extent the membrane is separable into two layers, between which there is a narrow cleft filled with a small amount of fat, and often occupied by a branch of the middle temporal artery. The two lamellæ are attached along the upper border of the zygomatic arch, the superficial layer being continued into the periosteum on the outer side of the bone. The fascia is separated from the integument by the thin membranous layer descending from the epicranial aponeurosis, and by the superior and anterior auricular muscles. It is pierced by the middle temporal artery, a small deep temporal vein, and by the zygomatico-temporal nerve.

The fascia consists of fascial and true aponeurotic fibres. The latter spread over the surface of the muscle in radial fashion from the inferior temporal crest and give origin to muscular fibres. Some bundles are also described extending upwards from the origin of the masseter on the zygomatic arch. The true fascial fibres can be distinguished from the aponeurotic by a difference in the direction in which they run. Careful analysis reveals various systems of such bundles in which the direction of the fibres varies. The fascial layer is fixed to the interval between the two temporal crests where it is continuous with the periosteum.

The **Masseteric Fascia**.—Over the cheeks we have to distinguish the proper fascial investment of the masseter muscle from the fascia covering the parotid gland. The latter is continued upwards from the fascia of the neck, and is connected above and in front with the masseteric fascia proper and the parotid duct. It is tough and fibrous, and is continuous with the fibrous framework of the gland. The true masseteric fascia is thin, especially over the tendon, and is firmly bound down to the muscle. It is attached above to the zygoma and to the periosteum of the mandible along the posterior border of the ramus, and to the body of the bone in front of the muscle. On the deep aspect of the parotid behind the angle of the mandible, a deep process of the cervical fascia bounds the space occupied by the gland and separates it below from the submandibular gland. It will be described along with the cervical fascia.

M. Masseter (figs. 21, 34, p. 66).—The masseter muscle is a thick quadrate muscle which is in close contact with the outer face of the ramus of the mandible, extending from the zygoma to the lower border of the bone. It is covered for the most part by the fascial layer described above, but is overlapped below by the platysma myoides and behind by the parotid gland. It is crossed by the duct of the gland, by some branches of the facial nerve, and by the transverse facial artery. The fibres of the muscle form two portions superficial and deep,

differing in size and direction. These two portions are distinct posteriorly, where they are separated by a space containing connective tissue, but they are inseparable anteriorly. The *superficial part* of the muscle, obliquely four-sided in form, arises from the lower border of the zygomatic arch as far back as the temporo-zygomatic suture. The origin consists mainly of tendinous bundles which extend for a variable distance over the outer face of the muscle, but lower in front than behind. From this tendinous expansion septa extend between the muscular fasciculi. On superficial examination the fasciculi of the muscle show a general parallel arrangement, but on analysis it is found that the muscle mass consists of interlocking bundles arranged bipennately on tendinous septa. The general direction of the bundles is downwards and backwards, and they are inserted into the lower part of the ramus of the mandible. In front the fibres are attached directly to the bone, but at the angle of the mandible they are fixed mainly by tendinous bundles to rough ridges upon the bone. The *deep part* of the muscle is triangular in shape, and consists of short vertical fleshy fibres which arise from the whole inner aspect of the zygomatic arch and the lower border of its temporal portion. Becoming united with the superficial part, they are inserted into the upper portion of the ramus, including the coronoid process. Some deep fibres, commonly described with the temporal muscle, but being supplied by the masseter nerve (Eisler) really belonging to the masseter, arise from the deep layer of the temporal fascia and blend with the masseter at their insertion. Only the upper and back part of the deep portion of the muscle is uncovered by the superficial portion.

Buccal Fat Pad.—Occupying the interval between the fore part of the masseter and the buccinator muscle is a mass of fine grained fat, definitely circumscribed by an investment of condensed fascial tissue. When well developed it overlaps the outer surface of the masseter and extends below it, and has various deep prolongations. Thus a process extends upwards and backwards between masseter and temporal muscles under the temporal fascia. Another process extends more deeply into the zygomatic fossa, and intervenes between the tuberosity of the maxilla, the deep surface of the temporal and the external pterygoid muscles, and is even continued into the pterygo-palatine (spheno-maxillary) fossa and thence with the orbital nerve into the orbit. The main mass on the buccinator muscle is specially well developed in the infant, and has been called the *sucking-pad*, because it is supposed to be of utility in preventing the indrawing of the cheek between the jaws in the act of sucking. The deep portions are certainly only masses of fat, which come to occupy the spaces between the muscles. They are specially well developed in man because the spaces referred to are larger than in the anthropoids, owing to the relative diminution of the masticatory musculature and the expansion of the skull. The superficial mass is probably only a similar accumulation of reserve fat, but mechanically it may serve the purpose indicated.

M. Temporalis (fig. 23).—The temporal muscle is a fan-shaped sheet lying in the temporal fossa, under cover of the temporal fascia with which it is intimately connected, except below where fascia and muscle are separated by the mass of fat referred to in the previous paragraph. The muscle arises by fleshy fibres from the whole of the temporal fossa with the exception of the anterior or malar wall. Along the inferior temporal line, however, the origin consists mainly of tendinous bundles. The more superficial of these bundles extend upwards to be continuous with the periosteum between the temporal lines, and expand below into a superficial aponeurotic layer, intimately blended with the fascia proper. The deeper fibres give rise to a series of tendinous lamella, from which the muscular fibres arise. Anteriorly, a separate layer, arising mainly from the fascia and the frontal process of the zygomatic bone, can be separated from the remainder of the muscle. The direction of the anterior fibres is nearly vertical, that of the middle fibres oblique, and that of the posterior fibres almost horizontal. The fasciculi, converging as they descend, end upon a tendon which appears in the

substance of the muscle, and is attached to the upper and anterior borders of the coronoid process. The superficial fibres are attached to the outer face of the tendon, but cease well above the process, so that the outer face of the tendon is exposed in the temporal fossa. The deep fibres arising in the temporal fossa are attached to the deep face of the tendon. They extend much lower down than the superficial fibres, and occupy the deep surface of the coronoid process, reaching as far as the union of the ramus with the body of the mandible, running here into continuity with the buccinator. A thin fascial lamella extends from the tendon of the temporal over to the buccinator (Hovelacque).

M. Pterygoideus Internus (fig. 26).—The internal pterygoid muscle is a strong quadrilateral sheet placed on the medial side of the ramus of the mandible somewhat in the same manner as the masseter is placed on the lateral aspect. It is separated from the jaw by the spheno-mandibular ligament, the internal maxillary vessels and their dental branches, the inferior dental and lingual nerves. It arises from the pterygoid fossa by fleshy fibres from the bottom of the depression and by tendinous fibres on each side. On the medial surface the tendinous fibres form an aponeurosis which extends a considerable distance in a downward direction. Here the muscle is closely related to the tensor palati muscle, and lower down to the superior constrictor of the pharynx. On the lateral aspect the tendinous expansion is less extensive. Slips are also derived from the lower and fore part of the lateral aspect of the pterygoid plate, from the tuberosity of the palate bone, and from the tuberosity of the maxilla. The slip from the maxilla, which is variable in the degree to which it is developed, constitutes a second head to the muscle. It lies superficial to the external pterygoid, while the main mass of the muscle at its origin lies deep to that muscle.

Superficially viewed, the muscle seems composed of parallel fibres, but on more careful analysis it is found to consist of bundles in which the fasciculi are bipennately arranged (Juvard). It is directed downwards with an inclination backwards and outwards, and is inserted into the rough mark between the angle and the mandibular foramen. The separate portions of the muscle are more distinct at the insertion, and end in tendinous lamellæ which are fixed to parallel ridges on the bone.

M. Pterygoideus Externus (fig. 26).—The external pterygoid muscle occupies the infratemporal (zygomatic) fossa. The deep surface lies against the upper and deep part of the internal pterygoid muscle, and the spheno-mandibular ligament more laterally. It arises by two fleshy heads placed close together, merged behind but separated by a triangular space in front. The superior head is attached to the infratemporal surface of the great wing of the sphenoid, and the infratemporal crest which separates it from the temporal fossa. The inferior head is larger, and arises from the lateral surface of the lateral pterygoid plate. The fasciculi pass backwards with an outward inclination, and converge to be inserted into the depression in front of the neck of the mandible and into the interarticular cartilage of the temporo-mandibular articulation. The internal maxillary artery reaches the pterygo-palatine (spheno-maxillary) fossa by passing between the two heads of the muscle.

Nerve Supply.—The four muscles above described are all supplied by the motor root of the mandibular division of the trigeminal nerve. The *temporal muscle* receives three separate branches. Two of these reach its deep surface by passing upwards between the upper border of the external pterygoid and the infratemporal crest. The foremost of these is distributed to the part of the muscle arising from the wing of the sphenoid and from the parietal bone, as well as to the greater part of the fibres attached to the squamous temporal, while the posterior twig, of smaller size, is confined to the lower and back part of the muscle. The third temporal nerve runs with the buccal branch through the cleft between the two heads of the external pterygoid, and ascends to supply

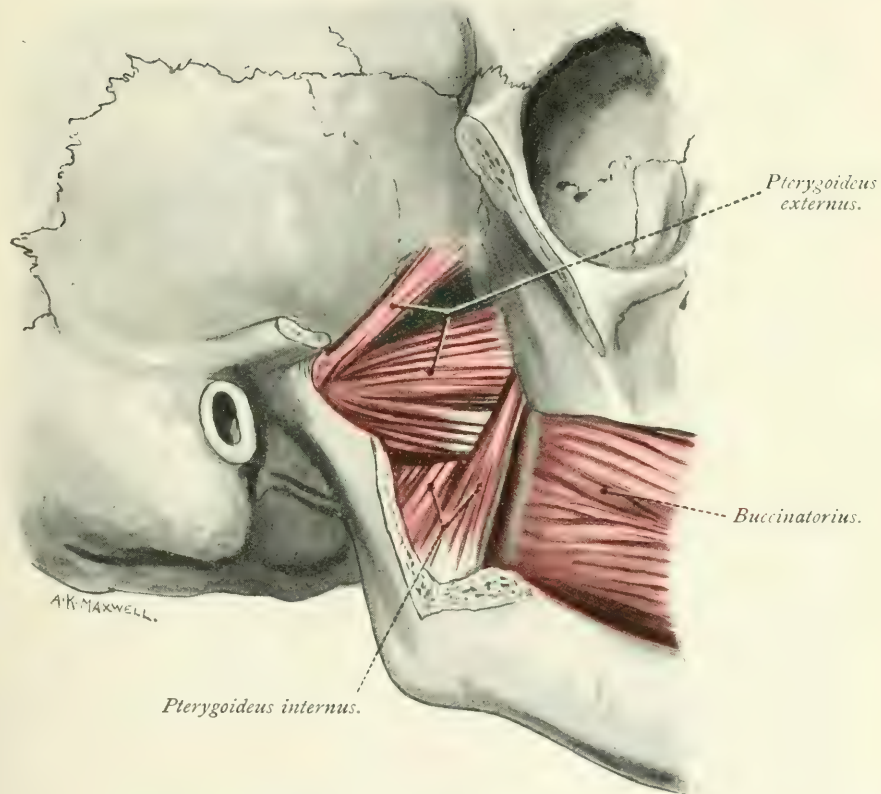


FIG. 26.—THE ZYGOMATIC ARCH AND RAMUS OF MANDIBLE HAVE BEEN REMOVED TO SHOW THE PTERYGOID MUSCLES.

the fore part of the muscle mass. The branch to the *masseter* reaches its muscle by passing outwards over the sigmoid notch of the mandible. It pierces the deep portion of the muscle and divides it into two parts. It gives off several branches as it enters the muscle, and divides within it into a large number of fine twigs destined for the component bundles of the muscle. The *external pterygoid* muscle receives its branch on the deep surface near the upper border of the lower head. The nerve gives off ascending twigs for the upper head. The nerve for the *internal pterygoid* is a slender branch which arises high up from the main trunk. It is closely related to the otic ganglion, and after a short course enters the deep surface of the muscle. A minute branch from the lingual nerve, presumably sensory in function, also enters the muscle (Fromont).

Variations and Morphology.—The masticatory group of muscles, as has been already noted, arise in ontogeny from a common rudiment. The same is probably true in the phylogenetic history of the group, but in all mammals the four muscles appear in one form or another, and variously developed according to the character of the masticatory movements of the jaw. In man, in keeping with the dimensions of the mandible and the character of the masticatory movements, the muscles are relatively weak, and none are disproportionately developed. The temporal muscle undergoes considerable expansion over the surface of the skull (Eisler), and occasionally the area of surface covered is extended and the muscle approaches the vertex. A racial difference in this respect seems to exist, for it would appear that the temporal area is more extensive in the lower races of mankind. In this connexion it may be mentioned that the *masseter* also varies a good deal in different races. The *masseter* and temporal muscles are connected by some deep fibres behind the zygomatic arch, and these being supplied by the *masseteric* nerve are to be attributed to the *masseter* (Eisler). Better developed in some lower mammals, they sometimes form a muscle described under the name *zygomatico-mandibularis profundus* (Toldt). Accessory bundles of the *masseter* may spring from the maxilla to the anterior border of the muscle, while others have been seen arising from the posterior part of the zygomatic arch and from the temporo-mandibular ligament. The insertion may spread to the cervical fascia, behind the angle of the jaw. A slip named *temporalis minor*, arising from the meniscus of the temporo-mandibular joint, is probably only a portion of the deep part of the *masseter*. In some cases fibres belonging to the *temporal* muscle have been observed arising from the lower part of the temporal crest behind, and attached to the zygomatic arch. The upper part of the *external pterygoid* may be absent or reduced to a tendinous slip, and the lower half may also be partly tendinous. A bundle of the muscle inserted on to the capsule of the joint may be isolated from the rest of the muscle by the maxillary artery or the sensory portion of the mandibular nerve. The *internal pterygoid* may be perforated by the artery; it sometimes exchanges fibres with the *tensor palati*, and may be joined with the *masseter* by fibres extending round the border of the mandible. The *pterygoideus proprius* (Henle) is the name given to a nearly vertical band of muscular and tendinous fibres, sometimes entirely tendinous, springing from the infratemporal crest and arching over the external pterygoid to the lower part of the posterior border of the external pterygoid plate, the tuberosity of the palate bone, or the maxilla. It has been seen sending a slip to the pterygo-mandibular ligament, or even to the mandible.

The *pterygo-spinosus* is a muscular slip occasionally seen springing from the spine of the sphenoid or tympanic plate of the temporal bone, and inserted into the hinder margin of the outer pterygoid plate, between the two pterygoid muscles. A fibrous band connecting these parts (*pterygo-spinosus*) is frequently present and is sometimes converted into bone (Vol. IV., Part I., p. 80). The ligament and muscle may co-exist.

Action of the Muscles of Mastication.—The lower jaw is depressed by its own weight and by the contraction of the *geniohyoid*, *mylohyoid*, and *digastric* muscles. The *platysma myoides* does not seem to be used in the ordinary movement. The contraction of the *suprahyoid* muscles requires the fixation of the hyoid bone, and for this purpose the *infrahyoid* and *lateral hyoid* muscles contract. When the jaw is forcibly opened the hyoid cannot be moved upwards or downwards. The *external pterygoid* muscle, since it pulls forwards the head of the mandible, has been described as taking part in the movement of opening the mouth (*v. Meyer*).

The muscles which raise the jaw are the *temporal*, *masseter*, and *internal pterygoid* muscles. These muscles act in concert, and do so with their maximum force when the lower teeth have been brought into contact with the upper teeth. The great power which they then possess is common knowledge. When the mouth is widely opened, however, these muscles lose a large proportion of their power, and in the dislocated jaw their actions are quite changed,¹ for the line of action of the *masseter* and *pterygoid* now lies behind the turning point of the jaw (the insertion of the *spheno-mandibular* ligament), and the contraction of these muscles only increases the opening of the mouth.

¹ This applies to the adult only, for in the old edentulous person these muscles retain their closing action even in the widely open mouth.

Forward movement of the jaw is performed by the external pterygoid muscles acting together, and the insertion of these muscles on the capsule causes the interarticular fibrocartilage to be drawn forwards at the same time. The masseter and internal pterygoid muscles can also effect forward movement.

Backward movement is performed by the posterior two-thirds of the temporal muscle, and by the digastric muscle when the hyoid bone is fixed.

The side-to-side grinding movements are effected by the alternate action of the external pterygoid muscles, while the elevating muscles of the side towards which the point of the jaw is moving also act. As a rule the opposite digastric muscle can be felt to contract at the same time.

THE MUSCLES OF THE ORBIT

In this group are included six muscles which move the eyeball, sometimes named the extrinsic muscles of the eye, and a seventh, already alluded to, which

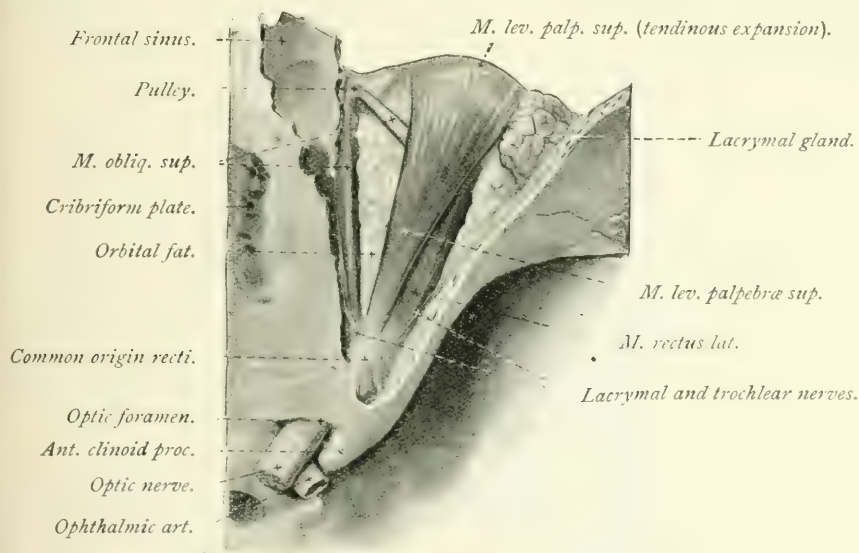


FIG. 27.—MUSCLES OF THE EYE EXPOSED BY REMOVING THE ROOF OF THE ORBIT. (Spalteholz.)

elevates the upper eyelid. Of the six muscles which move the globe, four, arranged symmetrically round the globe, run antero-posteriorly, and are named *rectus superior*, *rectus inferior*, *rectus medialis*, and *rectus lateralis*; two have an oblique direction and are called *obliquus superior* and *obliquus inferior*. The superior oblique is supplied by the trochlear nerve (IV.), the lateral rectus by the abducens (VI.). The remaining muscles receive branches from the oculomotor (III.).

All the seven muscles arise in the human embryo from a common premuscle mass, which can be recognised in an embryo of 7 mm. The oculomotor nerve is alone connected with the mass at its first appearance, but in embryos of 9 mm., the trochlearis and abducens nerves have entered the primordium, which now begins to undergo cleavage. The several muscles can all be detected in embryos of 14 mm., but the levator palpebrae superioris and the inferior oblique still remain incompletely separated from the superior and inferior rectus respectively. The levator palpebrae is produced by delamination from the superior rectus.

M. Levator Palpebrae Superioris (figs. 27, 30).—This is a slender muscle which arises by a short and narrow tendon from the back of the orbit above and

a little lateral to the optic foramen, from which it is separated by the origin of the superior rectus. The fleshy belly expands as it passes forwards over the eyeball, and ends just behind the supraorbital margin in a tendinous expansion or aponeurosis. This has a threefold insertion: (1) into the skin of the upper eyelid; (2) into the tarsal cartilage; and (3) into the orbital margins medially and laterally.

The cutaneous insertion is by radiating bundles of delicate fibrils which, passing between the fasciculi of the orbicularis palpebrarum, are attached to the whole of the pretarsal part of the eyelid. The attachment to the tarsal plate is partly by tendinous fibres, but mainly by a delicate lamella of non-striped muscle fibres, which are closely related to the deep surface of the aponeurosis, and are fixed along the upper margin of the cartilage.

This lamella of unstriped muscle appears to be continuous with the fleshy belly of the muscle, but is in reality an independent structure. There is a similar layer of involuntary muscle in the

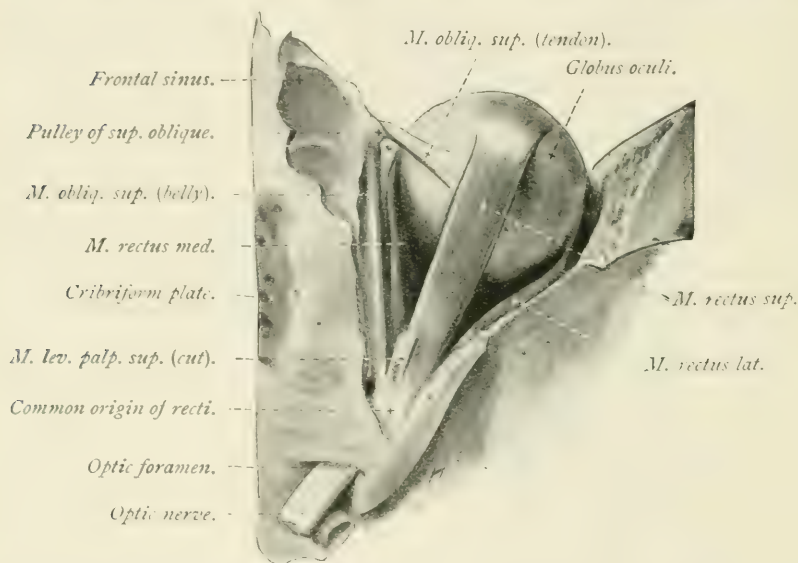


FIG. 28.—THE MUSCLES OF THE EYE EXPOSED BY REMOVAL OF THE ROOF OF THE ORBIT. THE LEVATOR PALPEBRÆ SUPERIORIS HAS BEEN REFLECTED AND THE ORBITAL FAT REMOVED. (Spalteholz.)

lower lid also attached to the margin of the tarsal cartilage, but its component fibres are not so regularly arranged, and therefore do not form so definite a lamella. These lamellæ are parts only of a nearly continuous layer, broken only laterally, of smooth muscle tissue connected with the fascial capsule of the globe behind and the lids in front (*musculus capsulo-palpebralis*, Hesser). Unstriped palpebral slips occur in all terrestrial mammals, but in aquatic mammals each rectus muscle has a palpebral slip of striped muscle. According to Groyer, the levator palpebræ represents the palpebral slip of the superior rectus retained in the case of the upper lid on account of its greater development. The striped palpebral slips when they occur are supplied by the same nerves as the muscles with which they are connected, while the unstriped musculature appears to be under control of sympathetic nerve fibres. Morphologically, therefore, they would seem to belong to different categories. In some mammals, in birds and lizards, there is a distinct depressor of the lower lid.

The attachment of the levator to the orbital margins is effected by the lateral extensions or horns of the membranous expansion of the tendon. The lateral horn, the stronger of the two, is attached to the zygomatic bone along with the

lateral palpebral ligament. The medial horn consists of strands which are continued into the medial palpebral ligament, and are attached with it.

The levator palpebræ sometimes gives off a slip from its medial border to the pulley of the superior oblique (*tensor trochleæ*), or less frequently a slip from its lateral border to the lacrymal gland (*retractor glandule lacrymalis*). The name *transversus orbitæ* is given to a slip of muscle arching from the medial to the lateral wall of the orbit, over the levator palpebræ, with which it is loosely connected.

Action.—The levator palpebræ superioris, as its name implies, is a simple elevator of the upper lid. It acts as the antagonist to the upper palpebral part of the orbicularis muscle. It presents the unusual feature of a combination with the striped muscle belly of a non-striped lamella. It is possible that the latter, which is probably under control of the sympathetic, may be responsible for maintaining the position of the upper lid, while the striped belly is concerned with the voluntary lifting of the lid.

Mm. Recti Oculi.—The *four straight muscles* have a continuous tendinous origin at the back of the orbit in the form of a fibrous ring or short tube of oval form (*annulus of Zinn*) (fig. 29). It is attached to the medial and upper edges of the optic foramen on the medial side, but laterally it bridges over the

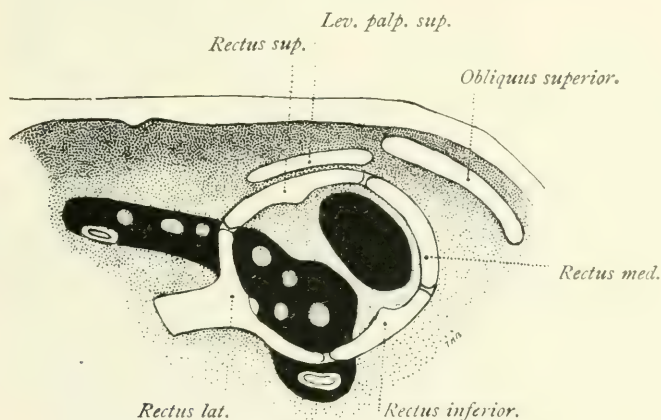


FIG. 29.—DIAGRAMMATIC REPRESENTATION OF THE ORIGIN OF THE RECTI MUSCLES FROM THE BACK OF THE ORBIT. (Annulus of Zinn.)

superior orbital (sphenoidal) fissure, and is fixed to its lower margin where a prominent tubercle is generally developed. The muscles arise from the outer aspect of this ring or tube, and are in contact by their margins all round it.

The **superior rectus** (figs. 28, 30) arises from the upper part of the ring, and is closely related to the optic nerve and adherent to its sheath. The **medial rectus** (fig. 28) has a wide origin from the ring, where it is fixed to the medial margin of the optic foramen, and is also closely applied to the nerve. The **inferior rectus** (fig. 30) arises from the lower part of the ring, where it is attached to the body of the sphenoid below the optic foramen, and at the medial end of the superior orbital fissure. It lies at a little distance from the optic nerve. The **lateral rectus** (fig. 30) arises from the part of the ring which bridges over the superior orbital fissure, and it is separated from the optic nerve by the structures entering the orbit through the fissure.

When the muscles are cut through and turned back, it is observed that the ring is thickened below and above and continued forwards as two delicate tendons on the deep face of the muscles. The lower (tendon of Zinn) is the stronger. It divides into three slips, one central from which the fibres of the inferior rectus

arise, and two marginal which spread on the ocular surfaces of the medial and lateral recti respectively, and give origin to the lower fibres of each. The upper tendon (tendon of Lockwood) likewise divides into three slips, a central for the superior rectus, and two marginal related to the medial and lateral recti, and giving attachment to the upper fibres of each. The four recti thus attached posteriorly, pass forwards, one above, one below, and one on each side of the eyeball, becoming flattened as they lie in contact with it. They are inserted by short membranous and slightly expanded tendons into the fore part of the sclerotic coat at distances of 5·8 to 7·8 mm. from the corneal margin.

The four recti muscles each measure about 40 mm. (Volkman), but there is a slight difference among them. The superior is the longest, the inferior the shortest. The medial rectus is the

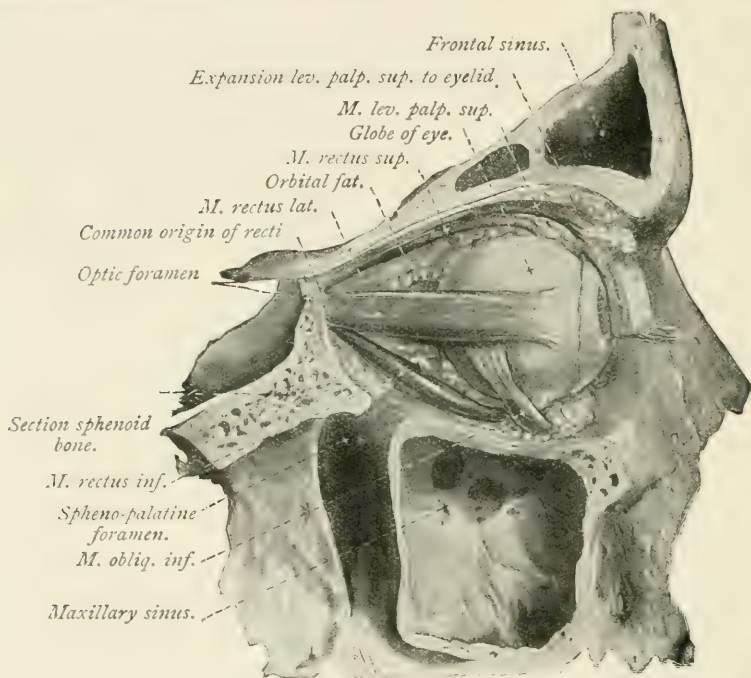


FIG. 30.—THE MUSCLES OF THE GLOBE OF THE EYE EXPOSED BY REMOVING THE LATERAL ORBITAL WALL. (Spalteholz.)

broadest and strongest, and the superior the smallest and narrowest of the four. At their insertions the edges of the tendons are slightly recurved so that a little pocket is formed under each. Further, some fasciculi leave the lateral margins of the tendon and are attached to the sclerotic some millimetres behind the main insertion. Of the tendons, that of the lateral rectus is the longest, that of the medial rectus the shortest. The insertion of the medial rectus approaches nearest to the margin of the cornea; that of the superior rectus recedes furthest from it (fig. 31).

Mm. Obliqui Oculi.—The **superior oblique muscle** (figs. 27, 28) is a narrow, elongated muscle, placed along the angle between the roof and medial wall of the orbit, medial to the levator palpebræ. It arises by a delicate tendon from the bone anterior and medial to the optic foramen, but separated from this by the origin of the medial rectus. Its muscular belly proceeds forwards along the medial wall of the orbit above the medial rectus, and ends in a rounded tendon which passes through a ring or pulley (trochlea) attached to the trochlear fossa

of the frontal bone. The pulley is formed of a ring of fibrous tissue in which a hoop of cartilage is developed. After passing through the pulley the tendon is reflected outwards, backwards, and downwards, and passes between the eyeball and the superior rectus to be inserted, under the lateral margin of this muscle, into the sclerotic coat on the posterior hemisphere (fig. 25).

The line of insertion cuts the vertical meridian of the globe obliquely at a point 16 to 17.9 mm. from the corneal margin (Fuchs), and is curved with the concavity directed forwards and medially. The greater part of the tendon lies to the lateral side of the meridian. In another type of insertion found in myopic eyes it falls wholly to the lateral side of the meridian and is more nearly parallel with it.

In lower vertebrates the superior oblique rises close to the inferior oblique from the antero-medial angle of the orbit. The two muscles pass round the globe, one above and one below in the equatorial plane. In mammals the direction of the muscles becomes more oblique, and in the case of the superior oblique a new belly arising from the back of the orbit is developed. In *Echidna* this and the anterior belly join together at the point of origin of the latter. In higher

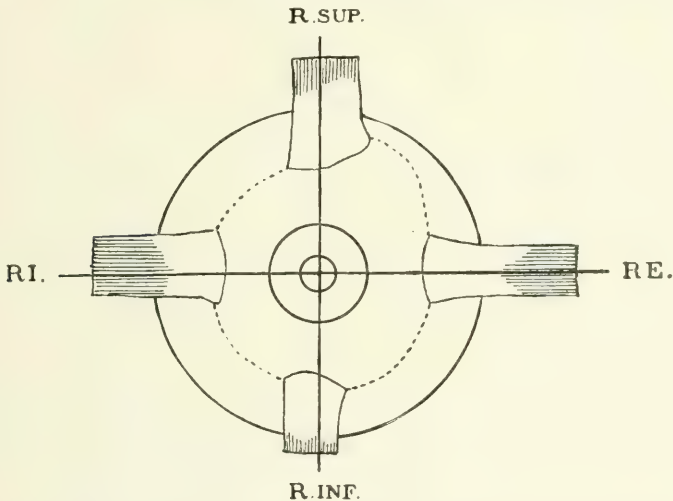


FIG. 31.—DIAGRAM TO SHOW THE PRECISE ATTACHMENT OF THE TENDONS OF THE FOUR RECTI MUSCLES TO THE SCLEROTIC IN RELATION TO THE CORNEA AND AXES OF THE GLOBE. (After Motais.)

mammals the forward bony origin is lost, and out of the sheath of muscle at this point the pulley is differentiated. With the replacement of the anterior belly by a tendon, as in man, the final stage of evolution is reached. Reversion to the primitive arrangement has been recorded, the posterior belly being absent, and the reflected tendon being replaced by a muscular slip attached to the usual site of attachment of the pulley.

The **inferior oblique muscle** (fig. 30) arises from a minute depression on the orbital plate of the maxilla, just within the anterior margin of the orbit and close to the lateral margin of the orifice of the naso-lacrymal duct. The muscle passes below the eyeball in a lateral and backward direction, and then turning upwards is inserted into the back of the globe in the lower lateral quadrant under the lateral rectus. The muscle has the form of a flat band, and crosses below the inferior rectus, to which it is bound by a fusion of the sheaths of the muscles to one another. The tendon of insertion is short, and is often absent, the muscle fibres being then attached directly to the sclerotic coat (Whitnall).

The line of insertion is much nearer the optic nerve than that of the superior oblique. Its distance from the corneal margin is from 17.3 to 19.1 mm. (Fuchs).

Varieties.—Congenital absence of the levator palpebrae has been recorded. The superior, medial, and lateral recti may also be undeveloped. The muscles are sometimes found connected by muscular slips. Thus the superior rectus may give off a slip to join the inferior rectus, or the inferior rectus one to join the superior. The lateral rectus has been seen giving off a slip to the inferior rectus or even to the medial rectus (Whitnall). The most interesting cases are those of slips which appear to represent vestiges of the retractor bulbi muscle. This muscle is present in lower forms from the amphibia upwards. It is supplied by the sixth nerve, and in its simplest form arises by a common belly with the external rectus. In the pig it is formed, according to Reuter, from all four recti, in the rabbit embryo from the lateral rectus only (Edgeworth). It may take the form of a muscular funnel surrounding the optic nerve and attached to the back of the eyeball, as in some ungulates and rodents, or it may be divided into four slips attached to the globe behind the recti and in the intervals between them. In the macaque among the monkeys it is represented by a single slip between the superior and lateral recti (Le Double). In man a muscular slip has been seen in the same position. In a case described by Whitnall there were four bundles present, arising from the fibrous ring at the back of the orbit. Each slip joined the deep surface of a rectus muscle. One slip was supplied by the abducens, the remainder by the oculomotor nerve.

Actions of the Muscles of the Eyeball.—The eyeball is kept in a position of equipoise in the orbit by the tonic action of the muscles. It appears to shift its place as a whole only to a slight degree, if at all, and does not undergo any perceptible change of form from the action of the muscles. The straight muscles acting in concert will tend to retract the globe, the oblique muscles to protract it. The globe is free, however, to rotate within the orbit on a fixed point, which lies nearly in the centre of curvature of the posterior wall and a little behind the middle of the antero-posterior axis, 14 mm. from the summit of the cornea, 10 mm. from the posterior pole. At this point the three primary axes intersect, and round these, or any intermediate axis, rotation may take place. Rotation round the antero-posterior axis, by which the vertical meridian is tilted clockwise or anti-clockwise, occurs to a limited degree only. The movements are insufficient to keep the eyeball in a fixed position during inclination of the head. As the antero-posterior axis is also the axis of vision, it follows that by rotation round the vertical or horizontal, or any intermediate axis, the line of vision can, within certain limits, be directed to various points in space, inwards, outwards, upwards, downwards, or in any intermediate diagonal. The six muscles co-operate in three pairs, the members of each pair alternately producing or controlling the movement round a particular axis.

In the horizontal movements the median and lateral recti muscles are the sole agents. As their line of action falls almost exactly in the horizontal plane of the eyeball, no rotation round the antero-posterior axis occurs. The movements are known as convergence or adduction of the cornea, and divergence or abduction of the cornea. In the up and down movements it is different. To produce pure elevation and depression the action of the oblique muscles must be associated with that of the superior and inferior recti. In the upward movement the superior rectus and inferior oblique are associated together; while in the downward movement the inferior rectus and superior oblique act in concert. The line of action of the superior and inferior recti does not coincide with the vertical plane of the eyeball, but forms an angle with it. Accordingly their primary action is associated with a secondary inward direction of the cornea and a slight rotation of the globe round its sagittal axis. Thus, taking the right eye, the superior rectus raises the cornea in an upward and inward direction and rotates the ball clockwise; the inferior rectus depresses the cornea in a downward and inward direction and rotates the ball anti-clockwise. Now the superior oblique, when the eye is in the primary position, directs the cornea downwards and outwards, and the inferior oblique moves it in an upward and outward direction. Both muscles being inserted on the lateral side of the centre of movement produce a certain amount of rotation round the sagittal axis, clockwise in the case of the superior and anti-clockwise in the case of the inferior oblique. But these movements, effected by the oblique muscles, are precisely those which are required to neutralise the inward direction and rotatory movements produced by the superior and inferior recti. Accordingly, by the combined action of the superior rectus and inferior oblique muscles a straight upward movement is effected in the vertical plane round the horizontal axis of the eyeball, while a similar effect in the downward direction results from the combined action of the inferior rectus and superior oblique muscles.

It has been further shown that in all the oblique movements of direction a combination takes place of the action of the oblique with that of the straight muscles. Here, however, two recti muscles are in action and are associated with one oblique muscle, as, for example, in the upward and inward direction the superior and internal recti with the inferior oblique, and in the downward and inward direction the inferior and internal recti with the superior oblique. And the same is true of the upward and outward and downward and outward movements of direction, for in all these movements the action of the oblique muscles is necessary to control or supplement the rotatory tendency of the recti muscles.

It is also obvious that the effect of the contraction of each muscle will vary according to the position of the eyeball. Thus, if the eye be abducted so that the transverse axis of the ball coincides with the axis of movement of the superior and inferior recti, these muscles will simply elevate or depress the cornea without rotation; whereas if the eye be adducted the rotatory tendency of the same muscles is increased, and requires a stronger effect on the part of the associated obliqui for its correction; and in extreme adduction the eyeball is elevated and depressed mainly by the inferior and superior oblique muscles, which have in great measure lost their rotatory action.

The ocular movements are always bilateral. But while in the upward and downward movements both eyes are always turned in the same direction, in the lateral movements the two eyes may either be directed to the same side, the one being abducted and the other adducted, or they may both be adducted so as to bring about the convergence of the visual axes necessary for near vision.

Fascia of the Orbit.—The space within the orbit which is not occupied by the eyeball and its muscles, or other parts belonging to it, is completely filled with soft fat and delicate connective tissue. In the earlier stages of development the eyeball and the parts connected with it are embedded in a continuous mesenchyme. As this becomes converted into connective tissue proper, it necessarily, in accordance with the principles laid down for all fasciæ, condenses into membranous layers or ligamentous strands, according to the natures of the stresses to which it is exposed. The general mass of the tissue forms the delicate stroma supporting the fat filling the orbit. It is condensed round the muscles into sheaths as elsewhere in the body, and round the eyeball it forms an adventitious capsule to the globe, investing it everywhere except over the cornea, where the surface epidermal layer becomes fused with the forward part of the true protective coat of the eye. Now by the action of the muscles the eyeball is moved within its connective tissue setting, and the adventitious capsule comes to form the wall of a sort of socket in which the globe rotates within certain narrow limits. Accordingly, between the globe and the capsule the connective tissue is reduced to a thin layer of extremely fine felted tissue. According to the more recent authorities, there is no true serous or lymph space between the globe and the capsule. As the globe is entirely surrounded by its adventitious fascial capsule, it follows that the muscles must pass through it on the way to their insertions into the sclerotic coat. In front of the slits through which the muscles pass the flattened tendons are placed in the episcleral space between the eyeball and the fascial capsule.

The *fascia bulbi* or *capsule of Tenon* extends from near the corneal margin, where it is fused with the sclerotic coat, to the optic nerve entrance. Over the front of the eyeball it is thin and delicate, and is closely connected with the ocular conjunctiva. Only a small amount of delicate areolar tissue intervenes between it and the globe. Behind, it forms a dense layer over the back of the eyeball. This is separated from the sclerotic by a potential space occupied by the fine felted tissue already referred to. Posteriorly it is continuous with the connective tissue stroma supporting the fat. Round the optic nerve it is pierced by the ciliary vessels and nerves, and is therefore somewhat cribriform. The muscle sheaths are likewise continuous with it and markedly thickened at these points. In a section of the orbital contents the ocular lamellæ of the several sheaths will necessarily appear to be reflected on to the back of the globe, there to form the back of the capsule within the muscle cone. The orbital lamellæ of the sheaths, on the other hand, appear to be carried forwards on the muscles to form the forward part of the fascial capsule. The muscle sheaths become greatly attenuated towards the apex of the orbit, and lend the appearance often described of a reflection of the capsule on the muscles. The sheaths are closely connected with the muscles as they pass through the openings in the capsule. In the case of the superior oblique, the reflected tendon is surrounded by a stronger investment which is continued to the pulley, but is reduced to a mere areolar layer on the muscular belly. In the intervals between the recti muscles the individual sheaths are united by thin membranes, which cover and retain the areolar tissue and its fat, where it lies within the muscular funnel. Medially and laterally the muscle sheaths are expanded into wing-like processes which are connected with the walls of the orbit, and form the so-called *check ligaments*. The lateral band is the stronger, and is attached to the tubercle on the zygomatic border of the orbit, to the lateral palpebral ligament, and the fornix of the conjunctiva. The medial expansion is similarly fixed to the crest of the lacrymal bone, the internal palpebral ligament, and conjunctiva. Both these so-called check ligaments include a small amount of non-striped muscular tissue. Above the eyeball it is found that the sheath of the levator palpebræ is bound to the fascial layer covering the tendon of the superior rectus, and the lamella of fascia thus formed is continued to the fornix of the conjunctiva. The upper layer of the fascial sheath of the levator finds attachment, by two horns, to the pulley of the superior oblique and the margins of the supraorbital notch medially, to the lacrymal gland and margin of the orbit laterally. Below the globe the sheath of the inferior oblique is fused with that of the inferior rectus as it passes beneath it. A fine lamella of fascia can be traced forward from this to the lower lid, and occasionally a stronger band or ligament is present, attached to the floor of the

orbit within the inferior orbital margin (check ligament of inferior oblique). The inferior rectus sheath is also connected, as in the case of the other straight muscles, by fascial bands to the sheaths of the medial and lateral recti. These in turn, as we have seen, are attached to the orbital walls, so that we have stretching from the medial to the lateral wall a fascial sling which supports the eyeball. This was originally described by Lockwood, and is known as the suspensory ligament.

THE MUSCLES AND FASCIA OF THE ANTERIOR REGION OF THE NECK

Comprised under this head there are several groups of muscles belonging to different morphological categories. The platysma myoides has already been dealt with as part of the cutaneous sheet of muscles. The trapezius and sterno-mastoid are in great part branchial muscles which have wandered backwards and acquired attachments to the limb girdle. Next follows a series of muscles which lie ventral to the visceral passages, and are connected with the hyoid bone. Above this they are continued to the mandible and tongue, the whole forming what in comparative anatomy are known as the hypobranchial spinal muscles supplied by the hypoglossal and certain anterior spinal nerves. They are to be referred to the ventral ends of the cervical, and probably also the occipital myotomes, and correspond to the rectus further back in the trunk. Associated topographically with the suprahyoid muscles of this group there are the mylo-hyoid, a derivative of the mandibular arch, and the digastric and stylohyoid muscles which are related to the hyoid arch.

A description of the pharyngeal muscles and those of the soft palate conveniently follows that of the suprahyoid muscles; thereafter that of the deep lateral and prevertebral muscles. The deep lateral muscles are all derived from the cervical myotomes. They extend from the cervical transverse processes to the first and second ribs, and are deeply placed under the trapezius and sterno-mastoid, but appear, after the deep fascia has been removed, in the triangular interval between those muscles along with the levator scapulæ muscle.

The prevertebral muscles are placed behind the pharynx and œsophagus on the front of the vertebral column. All the muscles of this deep lateral and prevertebral group are supplied by the anterior divisions of the spinal nerves.

The dorsal muscles of the neck belong to the dorso-lateral musculature supplied by the dorsal divisions of the spinal nerves, and being directly continuous with the corresponding muscles of the thorax will be more conveniently considered with them and those of the lumbar region in a later section.

The fascia of the neck which invests and separates the muscles from one another will best be described before the muscles.

Fasciæ.—The deep fascia of the neck resolves itself for descriptive purposes into a superficial investing layer, certain deeper intermuscular planes, and various ensheathing lamellæ. Most of the deep planes are merely septa of areolar tissue, rather than proper fascial membranes.

The *superficial layer* (fig. 32) extends under the superficial fascia and platysma myoides round the whole neck, but it varies greatly in density in different situations. Generally speaking, it is more delicate in texture where it underlies the platysma myoides. Over the trapezius muscle it is a relatively thin layer, which is continued on the surface of the muscle downwards to its insertion, and upwards to the superior curved line on the occipital bone. At the nape of the neck it is strengthened by transverse fibres, and is closely united with the dense superficial fascia which occurs in this situation. From the upper lateral border of the

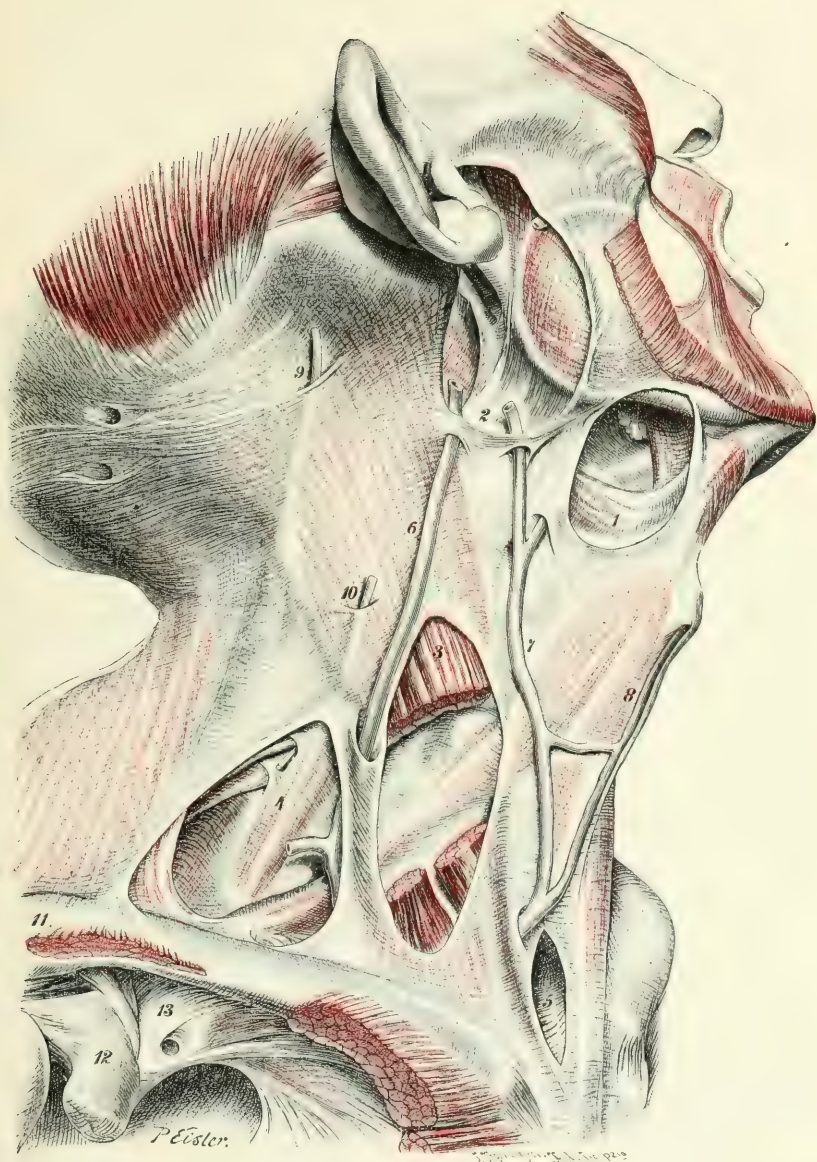


FIG. 32.—FASCIA OF THE NECK. (Eisler.) The superficial layer is opened up in several positions and partly removed to show the underlying spaces and the deep fascia; the sterno-mastoid is cut through; the submandibular and parotid glands have been removed.

1, submandibular space; 2, parotid space; 3, sterno-mastoid muscle in its sheath; 4, supra-clavicular fossa; 5, suprasternal space; 6, ext. jugular vein; 7, ant. jugular vein; 8, median vein of the neck; 9, small occipital nerve; 10, great auricular nerve; 11, deltoid muscle; 12, coracoid process; 13, coraco-clavicular fascia.

trapezius the superficial layer, often merging with the fascial plane coming from the deep surface of the muscle, passes forwards over the side and front of the neck under the platysma, gives a sheath to the sterno-mastoid, and is continued to the middle line of the neck, across which it passes without interruption. Over the posterior triangle—the great angular interval between the trapezius and sterno-mastoid muscles—it is relatively strong superiorly, but above the clavicle it is reduced to a thin lamella which is attached to the anterior border of the clavicle. This lamella is pierced by the descending cervical nerves, and near the bone at the posterior border of the sterno-mastoid muscle it is perforated by the external jugular vein, which in the previous part of its course lies on the surface of the membrane. Where it covers the sterno-mastoid the superficial lamella is thin below the platysma, but becomes dense and matted over the upper part of the muscle. Here it is connected with the skin, and is firmly attached to the superior curved line and mastoid process, at the insertion of the muscle. In the anterior triangle—the area bounded by the mandible, the medial border of the sterno-mastoid muscle, and the middle line of the neck—the fascia forms a membranous sheet, which below the hyoid bone covers the sterno-hyoid and omo-hyoid muscles, roofs in the carotid triangle, and is continued downwards, becoming stronger as it descends, to be attached to the front of the presternum, between the sternal heads of the sterno-mastoid muscles. Above the suprasternal notch it bridges over the gap between the projecting borders of the two muscles. Above the hyoid bone the superficial layer of the fascia extends over the anterior belly of the digastric and submandibular gland, to be attached to the border of the mandible. Further back below the ear, however, it is continued superficially upwards over the parotid gland to the zygoma. The fascia is firmly fixed to the angle of the mandible, and from this it sends a deep process, which separates the parotid from the submandibular gland, and in which the stylo-mandibular ligament is developed.

The parotid and submandibular glands are enclosed in definite spaces under the fascia (fig. 32), which it will be convenient to study at this point. The superficial lamella of the cervical fascia, which, as just stated, extends over the outer face of the parotid gland, is closely adherent to the connective tissue framework of the gland, and constitutes its capsule. The cervical fascia proper is utilised to only a small extent to form an inner wall to this space occupied by the gland. On the outer surface of the ramus of the mandible the gland rests on a thin fascia covering the masseter muscle, and there is no special deep capsular layer. But behind the jaw a deep strong process of the cervical fascia is prolonged inwards and backwards deep to the gland. It has the form of a triangular sheet of small extent fixed by its apex to the angle of the mandible. It extends upwards along the posterior border of the ramus, is attached medially to the styloid process and stylo-mandibular ligament, and thus forms a septum between the parotid and submandibular glands. It crosses the posterior belly of the digastric, merges with the fascia of the sterno-mastoid, and is continued below into the superficial fascial layer over the upper part of the carotid triangle. It ends laterally on the digastric muscle in a free border, round which, just above the muscle, the external carotid artery reaches the deep surface of the parotid gland.

The submandibular gland is not attached in any way to the fascia covering it. The fascial space in which it lies generally extends below the level of the hyoid bone, and here the superficial lamella gives off a deep process, which passes upwards over the stylo-hyoid muscle and the intermediate tendon of the digastric surrounding them in a loop. The deep limb of the loop is attached to the hyoid bone, and often forms a distinct pulley-like structure in which the tendon glides. Above this the fascia is prolonged as a very fine layer over the hyo-glossus to the side of the tongue. On the mylo-hyoid there is only a thin perimysial layer. The space can therefore hardly be said to have, except below and behind, a deep or inner wall provided by a splitting of the superficial layer of the cervical fascia.

To understand the disposition of the deeper lamella of the cervical fascia it is well to examine a cross section of the neck (fig. 33). It will be seen that the neck falls into two parts—a posterior, *vertebral*, occupied by the vertebral column and the muscles which surround and are attached to it; and an anterior, *viscero-*

vascular, occupied by the œsophagus, trachea, and thyreoid gland, the infrahyoid muscles on the front of the trachea, as well as the great vessels of the neck. These last lie, on each side, in the angle between the visceral tubes and the transverse processes of the vertebræ, and are covered laterally by the sterno-mastoid muscle in its fascial sheath. Behind the vertebral column a fibrous septum attached to the spines of the vertebræ (*ligamentum nuchæ*) occupies the median plane, and the muscles on each side of this are separated into layers, and isolated from one

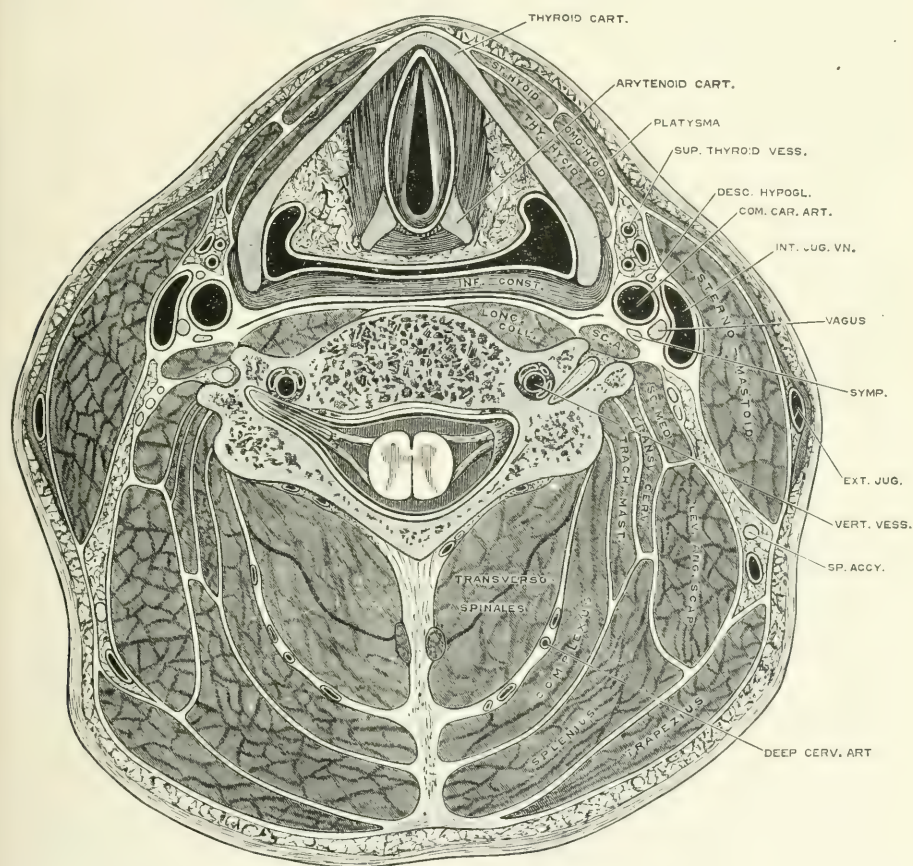


FIG. 33.—TRANSVERSE SECTION OF THE NECK THROUGH THE FIFTH CERVICAL VERTEBRA, REPRESENTING SEMIDIAGRAMMATICALLY THE ARRANGEMENT OF THE CERVICAL FASCIA. (After Braune and from Nature.) (G. D. T.)

The section passes through the upper part of the larynx, a little above the rima glottidis. The fascial planes are indicated by white lines, but it is to be observed that these are in many places not definite membranes, but merely layers of more or less dense connective tissue.

another by planes of connective tissue. In front of the column and extending from it latero-posteriorly are the prevertebral and deep lateral muscles of the neck. These muscles are covered by a fascial layer generally named the *prevertebral layer* of the cervical fascia. It consists of two sections: (1) it clothes the prevertebral muscles and extends with them from the base of the skull to the upper thoracic vertebræ; (2) it invests the deep lateral muscles (levator scapulae and scaleni), and sweeps laterally over them to be continuous with the deep fascia at the back of the neck. Behind the great vessels it is continuous with the fascial tissue

in which they are embedded (*carotid sheath*), and also supports the sympathetic cord in a special reduplication. Over the upper part of the posterior triangle the prevertebral layer fuses with the superficial lamella along the dorsal border of the sterno-mastoid, and sweeps with it backwards over the levator scapulæ on to the splenius muscle. In the lower part of the triangle the prevertebral layer is carried downwards on the scaleni muscles, and sweeping over the brachial plexus of nerves and the subclavian vessels, it passes on to the chest wall. Above the clavicle the prevertebral and superficial layers are separated by an interval in which are found the posterior belly of the omo-hyoid muscle surrounded by a loop of fascia presently to be described, a mass of fat, some lymphatic glands, the superficial cervical artery, and tributaries of the external jugular vein.

Turning now to the infrahyoid region of the neck: if a median incision be made through the superficial layer of the fascia above the suprasternal notch, it will be found that access has been obtained to an interaponeurotic space. This is bounded ventrally by the superficial layer, dorsally by a strong lamella, which, adhering to the infrahyoid muscles as they recede from the surface, is separated from the superficial layer as high up as about the isthmus of the thyroid gland, and is attached below to the interclavicular ligament and posterior border of the presternum. For part of its extent this space is closed on each side by the union of the superficial and deep layers along the borders of the sterno-mastoid muscles. But above the sterno-clavicular joints this union ceases, so that the space extends laterally behind each sterno-mastoid muscle forming the so-called lateral recesses of the suprasternal space.

The central space contains some loose connective tissue, fat, the communicating branch between the two anterior jugular veins (arcus venosus), and sometimes a lymph gland. The anterior jugular veins take their way through the lateral recesses, and breaking through the closing fascia, join the external jugular veins. Each lateral recess is bounded in front (behind the sterno-mastoid) by a thin layer of fascia which represents the deep layer of the sheath of the muscle, and is continuous with the superficial lamella of the suprasternal space.

The deep lamella forms the posterior wall of the recess, but it has other and more important connexions. It is prolonged lateralwards deep to the sterno-mastoid, fills up the angular gap between the intermediate tendon of the omo-hyoid, its posterior belly and the clavicle (fig. 35, p. 68), invests the central tendon of the muscle, and is wrapped round the posterior belly, giving it a continuous sheath, which extends along the muscle to its attachment on the upper border of the scapula. Beneath the sterno-mastoid it is closely bound to the deep lamella of the sheath of the muscle, but in the supraclavicular space it projects as a free fold between the layers of which the posterior belly of the omo-hyoid is placed, and by which, as by a sort of mesentery, it is bound down to the clavicle and first rib.

The deep suprasternal lamella is the anterior layer of the fascia investing the infrahyoid muscles. The deep layer of this fascia covers the deep surface of the muscles, and an intermediate divisional plane separates the superficial from the deep muscles. As we have seen, the anterior layer is fused above with the superficial investing layer of the cervical fascia above the level of the isthmus of the thyroid gland, but is separated from it below this level.

The somewhat complicated connexions of this deep or middle layer of the cervical fascia are at once made clear if one imagines the existence of a frontal sheet of fascia enclosing a great triangular continuous sheet of muscle, with its apex on the hyoid bone and its base attached to the sternum and to the clavicles, on each side, as far as the posterior bellies of the omo-hyoid muscles extend. Such a frontal sheet of muscle is realised in the reptilia (*episterno-cleido-hyoideus sublimis*, Furrbringer). In the human subject the clavicular portions of this sheet have disappeared on either side between the sterno-hyoid muscles, the posterior belly of the omo-hyoid, and the

clavicle. The investing fascial layers have fused in great part where the muscle has disappeared, but have retained the primitive arrangement medially round the sterno-hyoid and sterno-thyreoid in front of the trachea, and are preserved in part in the two lamellæ of the sheath of the posterior belly of the omohyoid. Beneath the sterno-mastoid the fascia has become more or less bound to the deep layer of the sheath of the muscle. In the supraclavicular space the posterior belly of the omohyoid covered by its sheath projects from the floor of the space—and it may be worth while to mention that there is a small pocket in front of the muscle and another deeper behind it. This last projects downwards and medially and contains some lymph glands, and, as the fascia forming its floor merges with the prevertebral fascia, the pocket is cut off from the axillary space below. The subclavian vessels lie behind the prevertebral layer (fascia of the scaleni muscles), and it is carried upon them into the axilla to form the axillary vascular sheath.

The great vessels of the neck along with the vagus nerve are embedded in connective tissue occupying the angular space in which they run. This tissue is to some extent condensed round the vessels to form the so-called *carotid sheath*, and a delicate septum divides the vein from the artery. The tissue round the vessels is necessarily connected with the fascial planes in its neighbourhood—behind to the prevertebral layer but not very firmly, in front to the deep lamellæ of the sheath of the sterno-mastoid, as well, of course, as the connective tissue on the deep face of the infrahyoid muscles where they overlies the vessels.

Laterally the sheath of the vascular bundle is continued into a plane of loose tissue and fat which intervenes between the sterno-mastoid and the prevertebral layer; medially it is continuous with the areolar tissue surrounding the trachea and larynx, the œsophagus, and the sides and back of the pharynx. According to Charpy and others, the medial wall of the carotid sheath is strengthened, and separated from the perivisceral space by a membranous septum which extends, on each side, from the prevertebral fascia and the roots of the transverse processes of the vertebræ to the œsophagus. These two lamellæ form as it were a mesentery for the digestive tube, between the layers of which the retro-œsophageal space is included. According to Eisler, the septa are not continuous membranes, but consist of separate bands of longitudinal and oblique fibres.

The posterior wall of the pharynx is provided with a distinct fascial layer, separated from the prevertebral layer of the cervical fascia by a space filled with areolar tissue, and enclosing the important retro-pharyngeal lymph glands. This *retro-pharyngeal space* extends from the base of the skull, behind the pharynx and œsophagus continuously into the thorax.

It is more or less separated below the hyoid bone, by the connexions of the connective tissue round the vascular bundle, from the cleft-like areolar tissue filled space between the infrahyoid muscles and the trachea and œsophagus, sometimes named the *previsceral space*. This space enlarging below is directly continued into the thorax in front and at the sides of the trachea, and the connective tissue occupying it is continuous with that of the superior mediastinum. In the neck the space is occupied by the thyroid gland, the inferior thyroid artery, and the recurrent laryngeal nerve, and includes some deep lymph glands. The thyroid gland is provided with a special connective tissue investment independent of the cervical fascia covering it. Lastly, round the trachea and œsophagus the connective tissue forms a perivisceral investment more or less definite, which, with the deep fascia of the infrahyoid muscles, binds the thyroid gland to the larynx and trachea.

M. Sterno-cleido-mastoideus (figs. 20, 21, 23, 34).—Placed immediately below the fascia of the neck the sterno-mastoid muscle extends the whole length of the neck in an oblique direction from mastoid process to sterno-clavicular articulation. It divides the quadrilateral space on the side of the neck into two great triangles. It is attached inferiorly by two heads, sternal and clavicular. The *sternal head* springs from the ventral surface of the presternum. It is thick and rounded, tendinous in front and fleshy behind. The fleshy fibres arising from this head occupy the whole breadth of the superficial aspect of the muscle. The *clavicular head* is flat, and composed of fleshy and tendinous fibres. It is

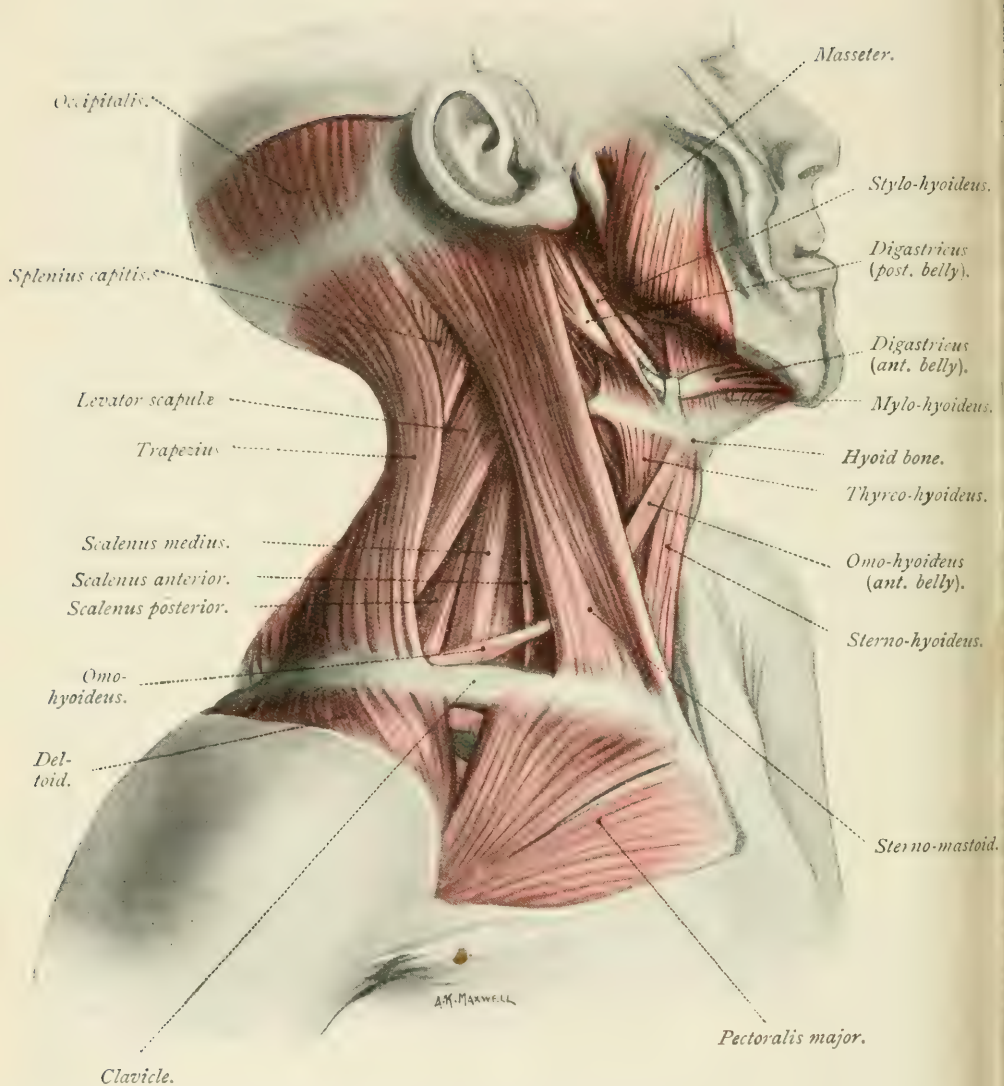


FIG. 34.—THE SUPERFICIAL MUSCLES OF THE SIDE OF THE NECK AS EXPOSED AFTER REMOVAL OF THE FASCIA.

attached to the medial third of the clavicle on its upper aspect and is separated from the tendon of the sternal head by a variable interval. The fleshy fasciculi course more vertically than those of the sternal head, and meet with them on the deep aspect of the muscle to form a thick prominent belly, which, extending upwards, outwards, and backwards, is inserted superiorly by short tendinous fibres into the anterior border and outer surface of the mastoid process, as well as a rough ridge directed backwards therefrom, and by a thin aponeurosis into the lateral half or more of the superior curved line on the occipital bone.

Relations.—The muscle is covered for more than the middle three-fifths of its extent by the platysma. It is also crossed by the external jugular vein and by the great auricular and superficial cervical nerves. It rests below on the part of the sterno-hyoid and sterno-thyroid muscles, and crosses the omo-hyoid. In the middle part of the neck it covers the cervical plexus, the great cervical vessels, and parts of the levator scapulæ and scaleni muscles, and in the upper part the splenius and digastric muscles. It is pierced by the accessory nerve.

Varieties, etc.—The muscle consists of two parts: *sterno-mastoid* and *cleido-mastoid*, separate below but fused above. These two parts may be separated by a fascial sheet, in which case, when they are detached from one another, the deep or cleido-mastoid portion is seen to be inserted separately by a rounded tendon into the tip of the mastoid process. The accessory nerve passes between the heads, or more commonly perforates the cleido-mastoid portion. Very frequently a third factor is added, the *cleido-occipital*, which arises from the clavicle in front of or outside the cleido-mastoid, and applies itself to the hinder border of the sterno-mastoid, being inserted in continuation thereof along the superior curved line. Still another variation occurs not infrequently, viz. the detachment of a slip from the dorsal border of the sterno-mastoid arising from the sternum and attached to the superior curved line. This may be described as the *sterno-occipital*. It is regarded by some as a fourth factor in the muscle, which thus analysed is seen to consist of four portions—sterno-mastoid, sterno-occipital, cleido-mastoid, and cleido-occipital. In some mammals the two mastoid sections are quite separate from one another, while the sterno-occipital and cleido-occipital are sometimes present, sometimes not. The sterno-mastoid, in some forms, consists of two layers, and Streissler adds the *sterno-mastoideus profundus* as a fifth component. In animals without a clavicle the cleido-mastoid and cleido-occipital are continued into the clavicular head of the pectoral, or deltoid, to form a cephalo-humeral muscle.

The clavicular head varies greatly in width, being sometimes as narrow as the sternal, while in other instances it extends as far as the middle of the bone; in such cases it may be divided into separate slips.

Various aberrant bundles have been described ending in various ways, such as a slip from the mastoid process ending on the fascial sheath of the carotid; a slip from the ventral border of the muscle to the hyoid bone; a slip from the deep surface to the cartilago triticea, which has been observed associated with a bundle to the hyo-glossus muscle. A slip may be given to the tympanic bone, stylo-mandibular ligament, or mandible at its angle. This last is of interest, because such an insertion occurs normally in ungulates. Gruber described a variety, also observed in the orang and chimpanzee, viz. the attachment of the muscle to the transverse process of the axis vertebra instead of to the mastoid process.

M. Trapezius (figs. 20, 21, 23, 34, 35, and 41, p. 91).—The trapezius muscle arises by a thin aponeurosis from the external occipital protuberance and medial third of the superior curved line of the occipital bone, from the ligamentum nuchæ, and from the spines of the last cervical and all the thoracic vertebræ, as well as from the supraspinous ligament. From this extended line of origin the fibres converge to their insertion. The superior fibres from the occipital bone and ligamentum nuchæ descending and turning forward in the neck, are inserted by fleshy fibres into the posterior border and upper surface of the clavicle along its lateral third. The fibres from the seventh cervical to the second or third thoracic spines pass transversely to the medial border of the acromion and cranial border of the spine of the scapula, to which they are attached by short tendinous fibres, as well as by deeper fleshy fibres. The tendinous fibres in specially well-developed muscles may extend over the acromion and spine into the origin of the deltoid muscle. The inferior fibres, ascending obliquely, converge on a triangular flat tendon which glides over

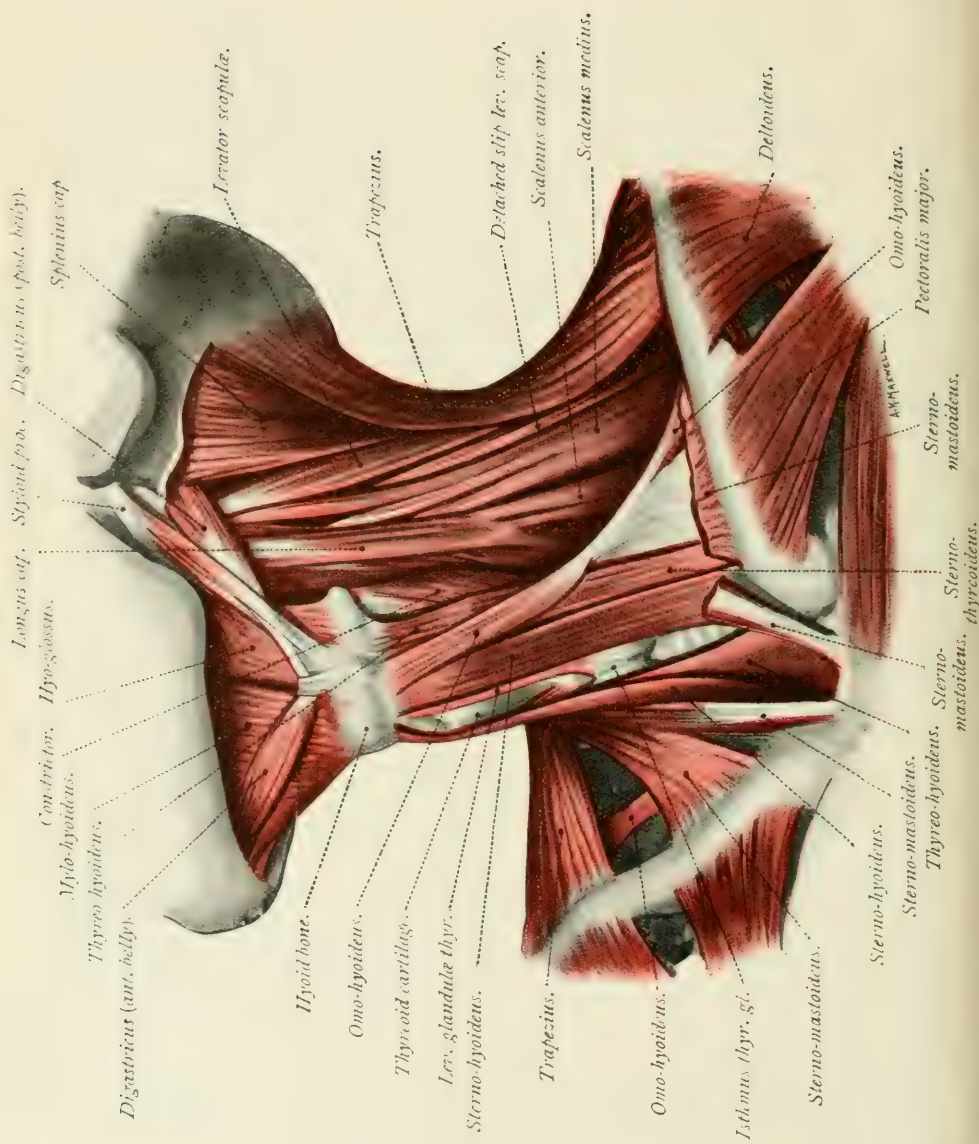


FIG 35.—MUSCLES OF SIDE OF NECK; DEEP DISSECTION.

the smooth triangular surface at the root of the spine of the scapula, and is attached to a rough prominence near the root of the spine. Below the tendon there is a small but constant bursal sac, while just in front of this between the muscle and the fascia covering the supraspinatus there is sometimes a bursa to be found.

The greater part of the line of origin shows only very short tendinous fibres, but in the lower part of the neck they become progressively longer to the level of the seventh cervical, and again shorten till the third thoracic spine is reached. Opposite the seventh cervical spine, and for some distance above and below it, an aponeurosis of elliptical form is thus produced interrupting the great four-sided muscular sheet formed by the two muscles. This sheet covering the upper part of the back, and suggesting a sort of hood or cowl, gave the name *cucullaris* to the muscle. At the caudal extremity of the muscle the tendinous slips from the last three or four thoracic vertebræ again elongate, and give rise to a small triangular aponeurosis with its apex directed downwards.

Relations.—The trapezius is superficial in its whole extent. It lies over the splenius, a part of the complexus semi-spinalis capitis above the splenius, the levator scapulæ, the rhomboidei, the supraspinatus, and small portions of the infraspinatus and latissimus dorsi. The accessory nerve and ascending branch of the transverse cervical artery pass into its deep surface.

Varieties.—There is very frequently a distinct amount of asymmetry of the trapezius muscles—the right, as to be expected, extending further back and having a more extensive attachment to the occipital bone than the left. The muscle sometimes only reaches the eighth or even a higher thoracic spine; more rarely it extends beyond the twelfth spine. The occipital origin varies in extent, and may be small or even wanting. The clavicular attachment may be reduced or more commonly extended along the bone to meet the border of the sterno-mastoid and cover over the supraclavicular triangle. In such cases there is generally a fibrous arch of larger or smaller dimensions for the supraclavicular nerves and often the external jugular vein. Occasionally, as happens in many lower mammals, the muscle is divided into a cervical and a thoracic part. It is to be noted that whether divided or continuous the mode of innervation is the same.

More extensive deficiencies, division into three portions or into isolated fasciculi, or even absence of the whole muscle, have been observed. The muscle may consist of two lamellæ. A detached bundle of longitudinal fibres on the surface of the thoracic part of the muscle, and named *M. dorso-fascialis*, has been described. Being supplied by the accessory nerve, it is to be considered as a detached portion of the trapezius which has undergone rotation (Renvall). Other small isolated muscular slips have been noted: (1) a slip from the border of the muscle, passing behind the omo-hyoid to reach the sternum (Gruber); (2) a slip below the trapezius on the surface of the rhomboideus major, springing by a flat tendon from the fourth to the sixth dorsal spines, and rising laterally and upwards to be attached by a narrow tendon to the vertebral border of the scapula along with the rhomboideus minor (Eisler).

Nerves of Supply to Sterno-mastoid and Trapezius.—Both muscles are supplied mainly by the accessory nerve. The nerve enters the sterno-mastoid on its deep surface about the junction of its upper with its middle third. In the substance of the muscle the accessory nerve is joined by a branch from the second spinal nerve. An extensive intramuscular plexus extends through the muscle common to its several parts. The supply is given partly by twigs from the plexus, partly by twigs direct from the accessory nerve, but there seems no regularity in the distribution of the direct branches to particular parts of the muscle. A twig from the hypo-glossal nerve has been observed, and Fromont states that the superior laryngeal nerve of the vagus also reaches the muscle (Poirier and Charpy).

The accessory nerve, after emerging from the posterior border of the sterno-mastoid, crosses the posterior triangle under the deep fascia, and passes below the anterior border of the trapezius muscle about the junction of its middle and lower thirds. It can be traced under the fascia on the deep face of the muscle, giving off twigs into the muscle as it descends. It extends as far as the middle of the lower or ascending section of the sheet, where it becomes intramuscular. Under the border of the muscle, two branches, one from the third, the second from the fourth cervical nerve, likewise pass to form with the accessory nerve a plexus from which twigs spring to enter the muscle. Various accounts are given of the part played by the accessory and the spinal nerves respectively in the innervation of the muscle, but they are not consistent. Some authorities state that the ascending part is principally supplied by the cervical nerves. It is not certain that this is the case.

Development and Morphology of the Sterno-mastoid and Trapezius Muscles.—The sterno-mastoid and trapezius spring from a rudiment placed below the occipital region on a level with the last two occipital and the two upper cervical myotomes (Lewis). Into this primordium passes the accessory nerve. The common mass of the two muscles gradually extends backwards, and in a 9 mm. embryo, having reached the level of the fourth cervical segment, it begins to split. The two divisions now separate and grow backwards independently towards the limb bud. The *sterno-mastoid* becomes attached to the developing clavicle, and later to the sternum. In a 14 mm. embryo it is fixed to the mastoid process and occipital region and to the clavicle, and is undergoing division into its two portions. The *trapezius* finds attachment to the spine of the scapula and clavicle, and is further displaced backwards with the descent of the limb girdle. It is at first only connected to the spines of the vertebræ by fascia. Later it spreads upward to the occipital part of the chondrocranium, and dorsally over the dorsal musculature towards the ligamentum nuchæ and the spines of the vertebræ. In a 20 mm. embryo it has obtained its permanent attachments, and has spread caudally to its full extent, viz. the level of the last thoracic spinous process. In the backward displacement the nerves of supply are necessarily carried with the muscles. The supply of both muscles by the accessory nerve indicates that the rudiment is primarily branchial in origin. The homologue of the trapezius in lower vertebrates definitely arises from the dorsal ends of the muscle bands in the branchial arches, and represents a fusion of certain of the levatores of the branchial arches (Edgeworth). In the rabbit it arises from the first three branchial rudiments (Edgeworth).

In all vertebrates below the reptilia the muscles are supplied solely from the vagus complex, but in man, as has been stated, they receive branches from spinal nerves. It is definitely denied by Lewis that the myotomes have any share in the upbuilding of the muscles. If this be so, then the innervation by spinal nerves must be a secondary one. But on the basis of a strict interpretation of the segmental supply, it is assumed that elements from the second myotome enter into the constitution of the sterno-mastoid, and from the third and fourth into that of the trapezius. The twig from the hypo-glossal to the sterno-mastoid, if admitted, would perhaps indicate that the first cervical myotome also takes a share.

Actions of the Sterno-mastoid and Trapezius.—The trapezius mainly acts on the shoulder girdle, elevating and rotating the scapula, as will be explained under the head of the action of muscles on the scapula. The sterno-mastoid muscles are concerned in the movements of the head on the vertebral column. Acting together, they bend forwards the head and neck towards the sternum. If one muscle acts alone, or rather acts in combination with synergic muscles on the same side, the head while it is slightly flexed is inclined laterally towards that side and is rotated to the opposite side. This is the attitude in wry neck, which is due to the spasmodic or organic contraction of one sterno-mastoid. Taking their fixed point at the head, the muscles can raise in combination the upper part of the chest in forced inspiration.

Anomalous Muscles in the Lateral Region of the Neck.—The *transversus nuchæ* has already been referred to (p. 36). It is mentioned again at this point because it was originally referred by Schulze to the sterno-mastoid. In some of the forms it assumes it belongs entirely to the facial group, but it is not certain that in all cases this is so.

The *omo-cervicalis* or *omo-trachelien* muscle is a rare variety. It occurs only in 2 per cent. of cases, but is of special interest because it is found, in one form or another, among lower primates as a normal muscle. It is attached above, in its most typical form, to the transverse process of the atlas, under cover of the trapezius, and here lies close to the levator scapulæ. Below it is inserted into the acromial end of the clavicle, or acromion process, or both, under the trapezius. It is supplied by the third or fourth cervical nerve, and possibly represents material from the myotomes of these segments normally suppressed, or incorporated in the trapezius.

The *supraclavicularis proprius* (Gruber) is a rare variety, and takes the form of a narrow muscular slip, attached at each end to the clavicle, and forming an arch above the middle of the bone, under which the supraclavicular nerves pass. It has also been seen ending in the fascia over the adjacent part of the trapezius. It is supplied by a twig from the third or fourth cervical nerve, and possibly comes into the same category as the last variety, with which it has been found associated in several instances.

The Infrahyoid Muscles

M. Sterno-hyoideus (figs. 23, 34, 35).—The sterno-hyoid muscle is a flat band of longitudinal fibres, arising variably from the back of the sternum and the posterior clavicular ligament, from that ligament and the clavicle, or from the clavicle only, and sometimes, to a small extent, from the cartilage of the first rib.

It is inserted by short tendinous fibres into the lower border of the body of the hyoid bone for its medial half.

M. Sterno-thyreoides (fig. 35).—The sterno-thyreoid, broader and shorter than the preceding muscle, under cover of which it lies, arises from the thoracic surface of the presternum lower down and nearer the median plane than the sterno-hyoid, and variably from the first and second rib cartilages. At its origin the muscle reaches the median plane, and often effects an interdigitation there with its fellow. It ascends from behind the sternum, diverging a little from its neighbour of the opposite side, and is inserted into the oblique line on the ala of the thyroid cartilage.

M. Thyreo-hyoideus (figs. 23, 34, 35).—This muscle forms a continuation upwards of the last. It arises by fleshy fibres from the oblique line on the ala of the thyroid cartilage, and is inserted into the lower border of the hyoid bone, extending over the lateral half of the body and medial half of the greater cornu.

Relations.—The sterno-hyoid is concealed below by the sternum and the sterno-mastoid muscle, higher up by the skin and fascia only. It lies on the sterno-thyreoid and thyreo-hyoid muscles, which it partly covers. The inner border approaches that of the corresponding muscle towards the middle of its extent, but is separated from it by a slight interval above and by a larger interval near the sternum. The outer margin is in contact with the omo-hyoid near the hyoid bone. The greater part of the ventral surface of the sterno-thyreoid is concealed by the sterno-hyoid, while its deep surface rests on the innominate vein, the lower part of the common carotid artery, the trachea, and the thyroid gland. The medial margin is contiguous with the muscle of the other side in the lower part of the neck. The thyreo-hyoid lies beneath the sterno-hyoid and omo-hyoid muscles. It rests on the thyroid cartilage and thyreo-hyoid membrane. Between the muscle and the membrane are placed the internal laryngeal nerve and vessels before they enter the larynx.

Varieties.—Both the sterno-hyoid and sterno-thyreoid occasionally show transverse tendinous intersections, that in the sterno-thyreoid placed at the level of the upper border of the sternum being almost constant. In the case of the sterno-hyoid an inscription is not infrequently present at the level of the intermediate tendon of the omo-hyoid, and a second may in rare cases occur at the level of the insertion of the sterno-thyreoid. A second inscription may also exist in the sterno-thyreoid at the level of the tendon of the omo-hyoid. These inscriptions are of morphological interest, as corresponding with the intersections of the rectus abdominis with which the infrahyoid muscles are homologous (p. 77).

The sterno-hyoid is sometimes divided longitudinally in its whole length, or cleft only in its lower portion, when of course it becomes a two-headed muscle. More rarely an accessory *cleido-hyoid* muscle may be present arising from the clavicle, and inserted into the hyoid bone medial and ventral to the sterno-hyoid. The insertion may extend over the hyoid, a slip joining the mylo-hyoid or even reaching the mandible (Walmsley). The absence of the muscle has been recorded. It may be fused with the sterno-thyreoid, or omo-hyoid, or with its fellow of the opposite side.

The sterno-thyreoid may be partially or wholly continued into the thyreo-hyoid, without interruption on the thyroid cartilage. Slips may also be given to the inferior constrictor, or the middle constrictor of the pharynx. Bundles may be given off to the fascia over the carotid vessels, covering them as high as the thyroid cartilage (*costo-fascialis*). These may exist while the upper part of the muscle fails, so that the muscle ends on the fascia (Walsham). The muscle has been seen split below into two layers, and also divided longitudinally into two or even three portions. An accessory fasciculus may arise from the clavicle. The absence of the muscle has been recorded in two cases. The *thyreo-hyoid*, as already stated, sometimes exists only as the continuation of the sterno-thyreoid. A division into two parts, medial and lateral, sometimes occurs. Some fibres frequently pass to the capsule of the thyroid gland forming one type of levator of that gland. Detached bundles may connect it with the hyo-glossus muscle and with the constrictors of the pharynx. A number of tiny muscles connecting the thyroid cartilage and great cornu of the hyoid bone described under different names are probably portions of the muscle segmented off. A slip named *kerato-thyreo-hyoideus*, occasionally present, can be traced, according to Edgeworth, to the branchial musculature, representing the first branchio-hyoid muscle of gilled vertebrates.

M. Omo-hyoideus (figs. 34, 35).—This muscle is a long, ribbon-shaped muscle consisting of two bellies united by an intervening tendon. It arises from the upper border of the scapula, near the suprascapular notch, and occasionally from the

ligament which crosses the notch. Thence it extends forwards and slightly upwards, across the root of the neck, till it passes beneath the sterno-mastoid muscle, and then curving rapidly, it ascends nearly vertically, to be inserted into the lower border of the hyoid bone immediately lateral to the sterno-hyoid. The intermediate tendon is placed beneath the sterno-mastoid and varies much in length and form in different bodies. It is enclosed within the deep fascia, which, after forming a sort of sheath for it, is prolonged downwards, and becomes attached to the sternum and cartilage of the first rib (fig. 35). By this means, as well as by fascia investing the posterior belly and descending to the clavicle, the muscle is maintained in its position.

Relations.—At its scapular origin the muscle is covered by the trapezius, in the middle of its course by the sterno-mastoid. The two bellies appear one in each of the triangles of the neck, the anterior crossing the common carotid artery, the posterior bounding the small triangle in which the subclavian artery is found. The muscle lies over the scaleni muscles, the lower cervical nerves, the carotid sheath, and the sterno-hyoid and thyreo-thyroid muscles.

Varieties, etc.—The omo-hyoid is a very variable muscle. Most of the more outstanding varieties find their explanation when it is recognised, as long ago shown by Gegenbaur, that the muscle is a portion of the same muscular sheet as the sterno-hyoid (*episterno-cleido-hyoideus superficialis*). This originally extended lateralwards to the scapula, but normally the greater part of the lateral expansion has disappeared, or has been replaced by the fascia binding the posterior belly to the clavicle. Some striped muscular fibres which this fascia has been seen to contain in the infant constitute a vestige of this sheet. The variations are accounted for by an increased or diminished cleavage in this sheet and the reappearance (or persistence) of parts normally suppressed. The intermediate tendon represents a tendinous intersection, and is little more than that in some cases. The origin of the posterior belly may be more extensive than usual on the scapular border, and may extend to the coracoid process or coraco-clavicular ligament. There may be an attachment to the clavicle at any point from the acromial end to the middle of the bone. This is the commonest variation observed, and may co-exist with the normal attachment, or may be the sole origin of the posterior belly. The clavicular head in the latter case may form a short posterior belly, the muscle being otherwise normal, or it may be united with the sterno-hyoid muscle. When a clavicular head thus joining the sterno-hyoid co-exists with a scapular origin more or less normal, as has been recorded in some cases, the absent part of the sterno-omo-hyoid sheet is almost completely restored. On the other hand, reduction may proceed further than it normally does, and the posterior belly may be replaced by a fibrous sheet, or the anterior belly may end by spreading out on to the fascia (*hyo-fascialis*). The anterior belly may also be reduced to a fascial band. The anterior belly may not be separated from the sterno-hyoid; it then ends below in a tendinous inscription common to it and the sterno-hyoid. Cases of complete absence have been recorded; on the other hand, the muscle may be doubled. From the anterior belly slips may be given to the fascia over the vessels, the hyo-glossus, the mylo-hyoid, even the genio-hyoid, or the sterno-thyroid. An accessory head has been described from the intermediate tendon to the hyoid bone. All these are not of the same morphological interest as the other varieties. From the posterior belly slips may be given to sterno-hyoid or sterno-thyroid or the sterno-mastoid, to the transverse process of the sixth cervical vertebræ or scalenus anterior. Remnants of the sterno-omo-hyoid sheet may also be seen in various small accessory slips, ending in the posterior belly, or the fascia, such as the *sterno-scapularis*, *coraco-cervicalis*, *cleido-fascialis*. Belonging also to the infrahyoid group is the *sterno-fascialis* arising from the presternum behind the sterno-mastoid and ending in the fascia of the omo-hyoid triangle.

The *sterno-clavicularis superior* or *supraclavicularis* is a small muscle not infrequently found which arises from the presternum near the upper border by a tendinous head behind the sterno-mastoid. It passes in front of the sterno-clavicular joint and is inserted into the dorsal border and dorsal surface of the clavicle as far as the middle of the bone. It is supplied by a special branch from the descendens hypoglossi nerve.

Nerve Supply.—The infrahyoid muscles are supplied by the first three (sometimes four) cervical nerves through the hypoglossal and ansa hypoglossi. The branch for the thyreo-hyoid comes from the trunk of the hypoglossal and enters the superficial surface of the muscle. The sterno-hyoid and sterno-thyroid both receive two branches, one for the anterior and one for the posterior part of each. The bellies of the omo-hyoid each receive a separate twig. The filaments for the thyreo-hyoid and the cranial portions of the other three muscles come from the first and second cervical nerves, those for the caudal parts from the second and third. The branches of supply pass between the superficial and deep layers so that the sterno-thyroid, like the thyreo-hyoid, receives its twigs on the outer aspect.

The Suprahyoid Muscles Connected with the Mandible

In this group four muscles fall to be described: the digastric and stylo-hyoid, mylo-hyoid and genio-hyoid. The muscles will be dealt with in topographical order. Morphologically, as already explained, they belong to different categories. The digastric, the stylo-hyoid, and the mylo-hyoid are branchial in origin; the genio-hyoid muscle belongs to the hypo-branchial group.

M. Digastricus (figs. 23, 34, 35).—The digastric muscle consists of two elongated fleshy bellies united by an intermediate rounded tendon. The posterior belly arises from the digastric fossa on the temporal bone, and is directed downwards, forwards, and medially, tapering gradually, towards the hyoid bone. The muscular fasciculi end pennately upon the intermediate tendon before reaching the hyoid bone. The anterior belly is attached to a rough depression on the lower border of the mandible close to the symphysis. It is shorter and broader than the posterior belly, and is directed downwards, backwards, and slightly outwards. The intervening tendon is connected to the body and great cornu of the hyoid bone by a broad band of aponeurotic fibres, and to a small extent by the fleshy fibres of the stylo-hyoid muscle through which the tendon passes. Fibres from the lower border of the tendon as it passes upwards with the anterior belly sweep into the dense sheet of fascia stretching above the hyoid bone over the interval between the two muscles, to form a more or less distinct fibrous arch above the hyoid bone. Sometimes the fascia round the tendon is thickened to form a sort of loop or pulley in which the tendon glides, or again there may be neither aponeurosis nor pulley. The bellies are then nearly in line and bound to the hyoid only by the arch of the stylo-hyoid.

M. Stylohyoideus (figs. 23, 34, 35).—The stylo-hyoid is a slender muscle placed along the upper border of the posterior belly of the digastric. It arises by a slender tendon from the back of the styloid process near the root, and inclines downwards and forwards, to be inserted into the hyoid bone at the union of the greater cornu with the body. Its fibres are usually divided into two fasciculi near its insertion, for the transmission of the tendon of the digastric muscle.

Nerves.—The posterior belly of the digastric is supplied from the facial nerve by a branch which comes off close to the exit of the nerve from the stylo-mastoid foramen, and also yields the twigs to the stylo-hyoid muscle. The anterior belly receives its supply from the mylo-hyoid branch of the mandibular division of the trigeminal.

Relations.—The posterior belly of the digastric muscle is concealed at its origin by the mastoid process, the sterno-mastoid, and splenius muscles. Under the parotid gland it crosses the internal carotid artery, jugular vein, and accompanying nerves, and with the stylo-hyoid crosses the external carotid artery still medial to the parotid gland. Below, the two muscles become superficial, but are overlapped by the submandibular gland. The anterior belly of the digastric is placed immediately beneath the deep fascia, and rests on the mylo-hyoid muscle. The lower part of the stylo-hyoid, the anterior belly of the digastric, and the border of the lower jaw bound a triangular space which contains the submandibular gland and is known as the submandibular triangle.

Varieties and Morphology. The digastric muscle is subject to many variations, chiefly affecting the anterior belly. The posterior belly is relatively constant. Its origin may extend backwards to the superior nuchal line, or to the styloid process, from which it may either arise entirely, or by an accessory slip. An accessory slip has been seen passing from the mastoid process or occipital bone to the hyoid, parallel to the digastric. In rare instances the posterior belly has been seen to end on the mandible, at the angle or about the middle of the body, the anterior belly being in this case absent or abnormal. The anterior belly presents many variations, and they may combine in different ways in individual cases. The anterior attachment may extend medially or laterally beyond the normal limits, and out of the different varieties can be constructed an ideal insertion in the form of a muscular sheet extending along the mandible from the angle to the digastric fossa and down the median raphe of the mylo-hyoid muscle to the hyoid bone. The normal belly is the central persistent part of the sheet. Thus bundles may sweep from the medial

side of the intermediate tendon or the fascia to the middle line, and there end on the mylo-hyoid raphe, or interdigitate with those of the opposite muscle, and fill the whole space between the anterior bellies (*bn. interdigastriæ*). Of these interdigastic fasciculi only the upper and lateral more longitudinal bundles, or only the lower and medial horizontal ones, may be present; or various combinations of oblique and transverse fibres may fill up the interval between the muscles. On the lateral side the attachment may extend a variable distance outward on the mandible. In this case the belly may be more or less normal, but the condition is generally, in the rare cases recorded, associated with the disappearance of the anterior belly as such. It is replaced by a broad band of fibres passing upwards and outwards to the mandible, from the mylo-hyoid raphe, the suprahyoid fascia, and the intermediate tendon which spreads out into the fascia. In some instances recorded, the extreme lateral part of the ideal sheet mentioned above may exist as an accessory head which joins the lateral border of the anterior belly. This, in such circumstances, may retain its normal form, or may, in greater or less degree, undergo the transformation just described. The *mento-hyoid* muscle is the name given to an occasional median slip found passing from the hyoid bone to the chin, separate from the digastric muscles; it sometimes consists of two parallel bands. The *stylo-hyoid* muscle may be absent on one or both sides, or fused with the gastric. On the other hand, doubling of the muscle has been recorded. Accessory slips may join the muscle from the origin of the digastric, from the stylo-mandibular ligament or the angle of the mandible. The muscle is occasionally placed on the inner side of the external carotid artery. The insertion may take place partly or wholly into the tendon of the digastric, or fibres are continued to the lesser cornu of the hyoid bone into the suprahyoid fascia or angle of mandible. The arch for the digastric tendon may not be complete; one or other limb may fail, so that the tendon may pass wholly in front or more rarely behind the stylo-hyoid. An additional muscular slip is occasionally seen (*m. stylochondrohyoideus*) passing from the styloid process to the lesser cornu of the hyoid bone, accompanying or replacing the stylo-hyoid ligament. The attachment to the lesser cornu is the commonest termination, but it may have other insertions.

The posterior belly of the digastric and stylo-hyoid are developed from the deep aspect of the pre-muscle mass at the base of the hyoid arch. Many homologies have been suggested for these derivatives of the hyoid arch. According to Edgeworth, they represent a levator hyoidei in series with the levator muscles of the branchial arches in lower vertebrates, and together correspond to the muscle known as the stylo-hyoid in monotremes. In higher mammals this is divided into posterior belly of digastric and stylo-hyoid. This subdivision is repeated in ontogeny, as the stylo-hyoid is only separated from the digastric at a comparatively late stage of development in man, according to the available data, which are, however, meagre. The anterior belly of the digastric seems to be developed from the ventral end of the muscle plate of the hyoid arch, and the nerve supply from the mylo-hyoid branch of the mandibular division of the trigeminal is secondarily acquired. This is a departure from the general rule, and the supply by the mylo-hyoid nerve would suggest that material from the mandibular arch is included in the rudiment, and comes to predominate in later stages. Edgeworth, however, as the result of his researches on the head muscles, states that there is a tendency for a muscle which shifts its position to acquire new or further supply from the nerve proper to the new position, so that the nerve supply is not an infallible guide to the morphology of a muscle. The point remains undecided. Edgeworth homologises the anterior digastric with a muscle, the *hyo-maxillaris*, separately developed from the hyoid muscle plate and found in some amphibians and in teleosts. In its digastric condition the muscle is peculiar to mammals. Three main types of digastric muscle are recognised: (a) There are two subequal bellies connected by an intermediate tendon as in man and some lower primates. (b) The intermediate tendon is greatly reduced but never wholly absent, and the muscle appears monogastric. It is always supplied by the two nerves and is attached to the mandible between symphysis and angle as in carnivores. (c) The bellies are unequal; a tendon extends between small posterior bellies across the front of the neck, and from the arch which these form large anterior bellies arise and touch one another in the median plane. This type occurs in many mammals and in most primates including the orang and chimpanzee. Some of the varieties described are reminiscent of one or other of these types. The literature of the digastric is voluminous. The more important papers are noted in the bibliographical appendix.

M. Mylo-hyoideus (figs. 23, 34, 35).—The mylo-hyoid muscle arises from the mylo-hyoid ridge on the inner surface of the mandible, extending from the last molar tooth almost to the symphysis. From this origin the fibres course, nearly parallel to one another, downwards and backwards to the median plane. The hinder fibres, also the longest, are inserted, shortly tendinous, into the body of the hyoid bone, while the larger number, becoming gradually shorter and more transverse as they are placed further forwards, meet at an angle with those of the

opposite muscle, and end upon a median tendinous raphe, which stretches from near the symphysis of the mandible to the hyoid bone. Thus the two muscles together form a floor beneath the anterior part of the mouth (*diaphragma oris*, Meyer).

The muscle is supplied by the mylo-hyoid branch of the mandibular division of the trigeminal nerve, several filaments entering its substance on its superficial aspect.

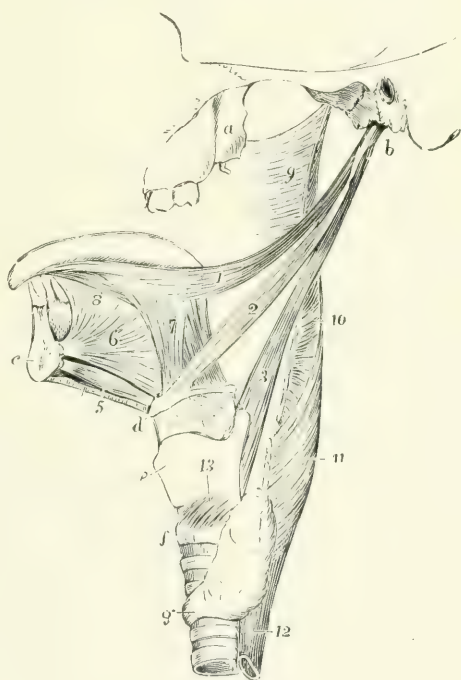
Relations.—The lower surface of the mylo-hyoid is in contact with the anterior belly of the digastric, the submandibular gland, the facial artery and its submental branch, and the mylo-hyoid vessels and nerve. The muscle covers the genio-hyoid, genio-glossus, and parts of the hyo-glossus and the stylo-glossus muscles, the sublingual gland, the duct of the submandibular gland, and the lingual branches of the trigeminal and hypo-glossal nerves. The posterior border alone is free, and round it the deep part of the submandibular gland turns.

Varieties.—The two mylo-hyoid muscles may unite with the disappearance of the raphe. The muscle may be divided into layers by processes of the submandibular gland. It may be inseparably united with, or even on one side be in great part replaced by the anterior belly of the digastric. It frequently receives an accessory slip from one of the other hyoid muscles, as the sterno-hyoid, omo-hyoid, or stylo-hyoid. A deficiency at the fore part of the muscle is of common occurrence, the origin not reaching further than the canine tooth. The mylo-hyoid seems to represent a muscle, the *intermandibularis*, which connects the ventral ends of the mandibular arches in lower vertebrates.

M. Genio-hyoideus (fig. 36).— The genio-hyoid muscle arises by short

FIG. 36.—MUSCLES OF THE TONGUE, PHARYNX, ETC., OF THE LEFT SIDE. (Allen Thomson.) $\frac{1}{2}$

a, external pterygoid plate; *b*, styloid process; *c*, section of lower jaw; *d*, hyoid bone; *e*, thyreoid cartilage; *f*, cricoid cartilage; between *d* and *e*, the thyreo-hyoid membrane; *g*, isthmus of thyreoid gland; 1, stylo-glossus muscle; 2, stylo-hyoid; 3, stylo-pharyngeus; 4, cut edge of mylo-hyoid; 5, genio-hyoid; 6, genio-glossus; 7, hyo-glossus; 8, lingualis inferior; 9, part of superior constrictor of pharynx; 10, back part of middle constrictor; 11, inferior constrictor; 12, upper part of œsophagus; 13, crico-thyreoid muscle.



tendinous fibres from the inferior mental spine behind the symphysis of the jaw. It extends downwards and backwards, under cover of the mylo-hyoid and in contact with its fellow, and broadening out as it goes, is inserted into the anterior surface of the hyoid bone.

It is supplied by a branch from the hypoglossal nerve, bringing to it fibres from the first and second cervical nerves, and possibly some from the cranial nucleus.

Varieties.—The genio-hyoid is sometimes blended with the muscle of the opposite side. It has also been found double. It commonly sends a slip to the great cornu of the hyoid bone, and is sometimes united more or less with the hyo-glossus and genio-glossus.

It is developed in close association with the extrinsic muscles of the tongue from a common premuscle mass, which is continuous behind with that of the infrahyoid muscles (see under Tongue Muscles). The nerve supply indicates its close association with the infrahyoid group and its probable myotomic origin.

Actions of the Muscles of the Front of the Neck. The muscles attached to the hyoid bone come into action in mastication, deglutition, and to some extent in phonation. The *digastric*, *mylo-hyoid*, and *genio-hyoid* are elevators of the hyoid bone, or depressors of the mandible, according as one or other of these bones is fixed by the antagonistic muscles. The stylo-hyoid acts only on the hyoid bone. The mylo-hyoid further raises the floor of the mouth and presses the tongue against the palate, thus forcing back the food in the first stage of deglutition. The infrahyoid muscles fix the hyoid bone, and act therefore synergically with the suprahyoid muscles in depression of the mandible. The *sterno-hyoid* and *omo-hyoid* act directly as depressors of the hyoid bone. The *sterno-thyreoid* and *thyreo-hyoid*, acting in conjunction, have the same effect. The last-named muscle raises the thyreoid cartilage when the hyoid bone is fixed. Acting all together, these muscles restore the position of the hyoid bone and larynx after they have been raised in the act of swallowing. The thyreo-hyoid muscles, by drawing the thyreoid cartilage upwards under the hyoid bone, are the principal agents in producing the descent of the epiglottis on the upper opening of the larynx during deglutition. In the utterance of low notes the larynx and hyoid descend below the natural level in the direction of the sternal muscles, while in the utterance of high notes there is a little elevation of the hyoid bone; but the larynx is raised by the thyreo-hyoid muscles. The muscles attached to the cartilage fix the larynx during the contraction of certain of the laryngeal muscles in phonation. The hyoid muscles act with the sterno-mastoids in forced inspiration.

The Extrinsic Muscles of the Tongue

The tongue is a muscular organ attached posteriorly to the hyoid bone, and inferiorly to the mandible. It is comprised partly of fibres peculiar to itself—the *intrinsic* muscles, which have been noticed with the special anatomy of the tongue in Vol. III., and partly of muscles arising from neighbouring parts—the *extrinsic* muscles now to be described. They are the *genio-glossus*, the *hyo-glossus*, and *stylo-glossus*.

M. Genio-glossus (fig. 36).—The *genio-glossus* is a fan-shaped sheet of muscle placed vertically in contact with its fellow in the median plane. It arises by a short tendon from the superior mental spine behind the mandibular symphysis. From this point its fasciculi diverge, to be inserted as follows: The inferior pass backwards to be attached for the most part to the body of the hyoid, and a few into the side of the pharynx; the superior turn upwards and forwards to the tip of the tongue; while the intermediate fibres extend into the whole length of the tongue, spreading outwards in its substance. Some of the innermost fibres, as they enter the tongue, decussate across the middle line with those of its fellow muscle.

Varieties.—Occasional slips of this muscle have been noticed passing to the epiglottis or to the stylo-hyoid ligament, or more frequently to the small cornu of the hyoid bone. It has also been found united with the *genio-hyoid* muscle. A small separate slip (*genio-glossus accessorius*) has been described arising from the lower part of the mental spine and joining the main mass of the muscle below.

M. Hyo-glossus (figs. 23, 35, 36).—This is a flat quadrate muscle, arising from the whole length of the great cornu and from the lateral part of the body of the hyoid bone. It passes vertically upwards to the posterior half of the tongue close to its lateral border, whence its fibres spread forwards and inwards over the dorsum, joining those of the *stylo-glossus*.

The **chondro-glossus** is a small flattened slip of muscle sometimes described as a portion of the *hyo-glossus*, from which, however, it is separated by the pharyngeal fibres of the *genio-glossus*. It comes from the inner side of the base of the small cornu and from the body of the hyoid bone, and its fibres are directed upwards and forwards, spreading somewhat, to end on the dorsum of the tongue by the side of the middle line. It is sometimes wanting.

Varieties.—Besides the chondro-glossus, certain other small muscular slips have been described. The *triticeo-glossus* is a small muscle which arises from the cartilago triticea in the thyreo-hyoid ligament, and passes upwards and forwards, lying on the medial side of the lingual artery, to enter the tongue with the posterior part of the hyo-glossus. This has been seen associated with a slip from the medial surface of the sterno-mastoid to the cartilago triticea. The three elements of the muscle, basi-glossus, cerato-glossus, and chondro-glossus, are distinct in many mammals, and may be more or less so in the human subject. The origin of the muscle is sometimes pierced by the lingual artery.

M. Stylo-glossus (figs. 36, 37, 38).—The stylo-glossus arises from the front of the styloid process near its point, and from the stylo-mandibular ligament, to which in some cases the greater number of its fibres are attached. It passes forwards and a little downwards and medialwards, and is attached along the side and under part of the tongue as far as the tip, its fibres decussating and becoming blended with those of the hyo-glossus and palato-glossus.

Varieties.—Absence and doubling of the stylo-glossus have both been noted. The name *mylo-glossus* has been given to a slip of muscle which arises from the mandible posteriorly above the molar teeth, and passes to the base of the tongue. The stylo-glossus may receive accessory slips from the angle of the mandible and the stylo-mandibular ligament. Occasionally the whole muscle arises from one of these points, or from the surface of the internal pterygoid. The *stylo-auricularis* is a muscular slip, occasionally seen springing from the cartilage of the external meatus of the ear close to its attachment to the bone, and ending below on the styloid process, or passing in whole or in part into the stylo-glossus. A fibrous band is often found in this situation. In some mammals, *e.g.* the seal, the muscle arises normally in this way, not from the styloid process.

Relations of the Extrinsic Muscles of the Tongue.—The hyo-glossus, except at its posterior inferior angle, where it appears in the carotid triangle, is concealed by the digastric, stylo-hyoid, and mylo-hyoid muscles. The deep part of the submandibular gland rests on its surface, and it is crossed by the hypoglossal nerve, the duct of the submandibular gland, and the lingual nerve in that order from below upwards. It covers the hinder part of the genio-glossus, the lower end of the stylo-hyoid ligament, and the origin of the middle constrictor of the pharynx together with the lingual artery and glosso-pharyngeal nerve.

The stylo-glossus lies deeply beneath the parotid gland and the angle of the mandible, and is crossed by the lingual nerve. On the side of the tongue it lies above and lateral to the hyo-glossus. Medially it is related to the inferior lingualis and the genio-glossus. The genio-glossus lies beneath the mylo-hyoid in front and the hyo-glossus behind. The lateral surface is in contact with the hyo-glossus, the inferior lingualis, and the stylo-glossus muscles, the sublingual gland, and the ranine vessels. Its lower border is in relation to the genio-hyoid. The terminal portion of the hypoglossal nerve enters its posterior part.

All the extrinsic muscles of the tongue are supplied by the hypoglossal nerve.

Actions.—The *genio-glossus* has a complicated action, the back part protruding, and the fore part retracting the tongue, while the middle part, or nearly the whole muscle, acts as a depressor. The *stylo-glossus* draws the tongue backwards, and elevates its base. It thus comes in play in deglutition. The muscle of one side acting alone gives a lateral direction to the fore part of the tongue. The *hyo-glossus* and *chondro-glossus* retract and depress the tongue. The two genio-glossi and the two stylo-glossi acting in conjunction tend to make the dorsum of the tongue concave, while the hyo-glossi produce a convexity.

Development and Morphology of the Hypo-branchial Group of Muscles.—The hyoid muscles are developed, as has already been stated, from a column of premuscle tissue lying below the pharynx and continuous behind with the rudiment of the diaphragm. Lewis states that he could not trace, in the human embryo, a connexion at any time with the myotomes, but in the rabbit (Edgeworth) they originate from downgrowths from the first three trunk myotomes, which fuse to form a longitudinal column. This divides into genio-hyoid and primitive sterno-hyoid by attachment to the hyoid bone. The primitive sterno-hyoid then divides into definitive sterno-hyoid, omo-hyoid, sterno-thyreoid, and thyreo-hyoid muscles. The longitudinal column clearly corresponds to a continuation forwards to the mandible of the rectus system of the trunk. In the lowest vertebrates this column is already divided into an anterior pre-hyoid and a posterior post-hyoid section. The latter finds attachment posteriorly to the coracoid bone forming a coraco-hyoideus. The anterior part grows backwards over the coraco-hyoideus, and overlapping it in various degrees finds attachment to branchial arches or to coracoid; thus a coraco-mandibularis is formed (Edgeworth). With the development of the sternum in higher vertebrates, the

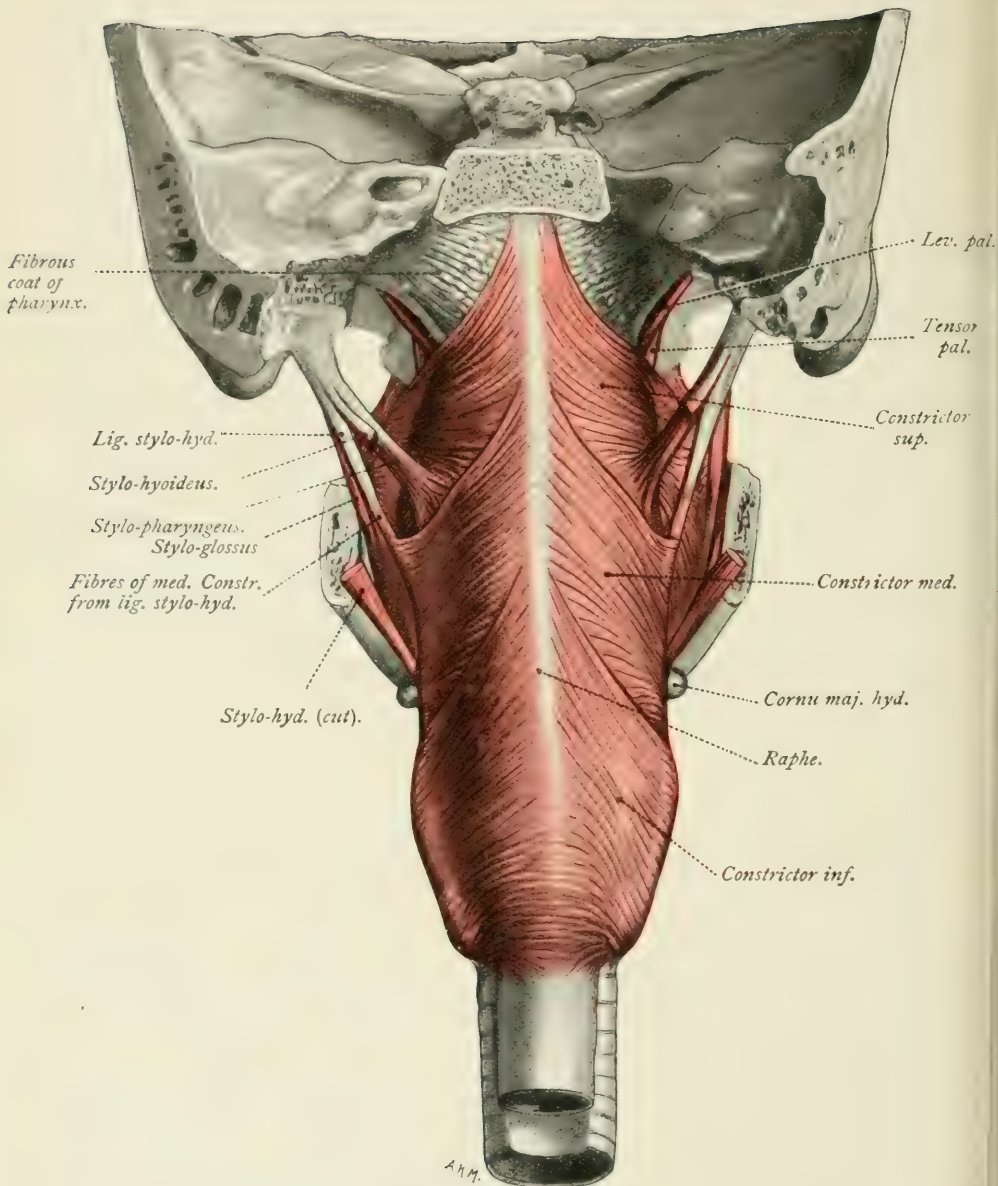


FIG. 37.—THE MUSCLES OF THE PHARYNX ; POSTERIOR VIEW.

column acquires attachment to it, while retaining the connexions to the pectoral girdle in various ways.

The tongue muscles take origin from the primitive genio-hyoid mass in the anterior end of the hypo-branchial muscle column. The genio-glossus originates from the medial, the hyo-glossus and stylo-glossus from the latero-dorsal portion of the common mass, and the hypoglossal nerve enters the caudal part of the rudiment. The hypo-branchial musculature is supplied, as we have seen above, from a plexus of nerves which originates in the embryo by a union of the hypoglossal with the upper cervical nerves. The supply of the tongue muscles from the hypoglossal trunk would indicate, on analogy with lower forms, that they owe their origin to the occipital myotomes.

THE MUSCLES OF THE PHARYNX

The pharynx, the dilated upper portion of the alimentary tube, extending from the base of the skull to the œsophagus, presents a continuous wall at the sides and back, but is open in front towards the nose, mouth, and larynx. The wall is, in great part, formed and supported by distinct muscles, which are disposed in two layers. The outer layer, in which the fasciculi have a generally transverse direction, consists of three muscles named *constrictors*. These have their fixed points in front, being attached to bones or cartilages, while behind, greatly expanded and overlapping one another from below upwards, they end by joining their fellows in the middle line to form a median tendinous raphe. The inner layer comprises the *levator* muscles of the pharynx, two in number, viz. the stylo-pharyngeus and the palato-pharyngeus. The first will be described here, the second with the palatal muscles.

The pharynx is developed from the foregut which lies in the head region. The pharyngeal muscles represent the proper visceral musculature of the foregut, differing from the visceral musculature of the trunk in being separated into individual muscles and composed of striped muscular fibres. These distinctions are probably to be explained on functional grounds. All the muscles of the head previously described except those of the eye are derived from the muscle plates of the branchial arches. The pharyngeal and palatal muscles are to be regarded as derivatives of the splanchnic mesoderm like the rest of the visceral musculature.

M. Constrictor Inferior (figs. 37, 38).—The inferior constrictor, the broadest and thickest of the three, arises by a series of slips from the sides of the cricoid cartilage at its lower and posterior part, as well as from the inferior cornu, the oblique line and upper tubercle of the thyreoid cartilage. Some fibres are also continued into it, as a general rule, from the sterno-thyreoid and crico-thyreoid muscles. It curves backwards and medianwards, and unites with its fellow in the middle line at the back of the pharynx. The inferior fibres are horizontal in direction; the rest ascend with increasing degrees of obliquity. The highest end on the raphe about an inch below the basilar process. From its lower border a few fibres turn downwards into the longitudinal fibres of the œsophagus.

M. Constrictor Medius (figs. 37, 38).—The middle constrictor arises from the greater and lesser cornu of the hyoid bone, and from the stylo-hyoid ligament. Its fasciculi diverge widely as they sweep round the pharynx and end in the middle line along nearly the whole length of the pharynx. The lowest fibres incline downwards beneath the inferior constrictor, the highest ascend to overlap the superior constrictor; the intermediate fasciculi run transversely.

M. Constrictor Superior (figs. 37, 38) arises by fibres attached in series from below upwards, to the side of the tongue, to the mucous membrane of the mouth, to the extremity of the mylo-hyoid ridge on the mandible, to the pterygo-mandibular ligament, to the hamular process and lower third or less of the posterior border of the medial pterygoid plate. The fibres curve backwards, and are mostly blended with those of the corresponding muscle along the middle line, a few ending

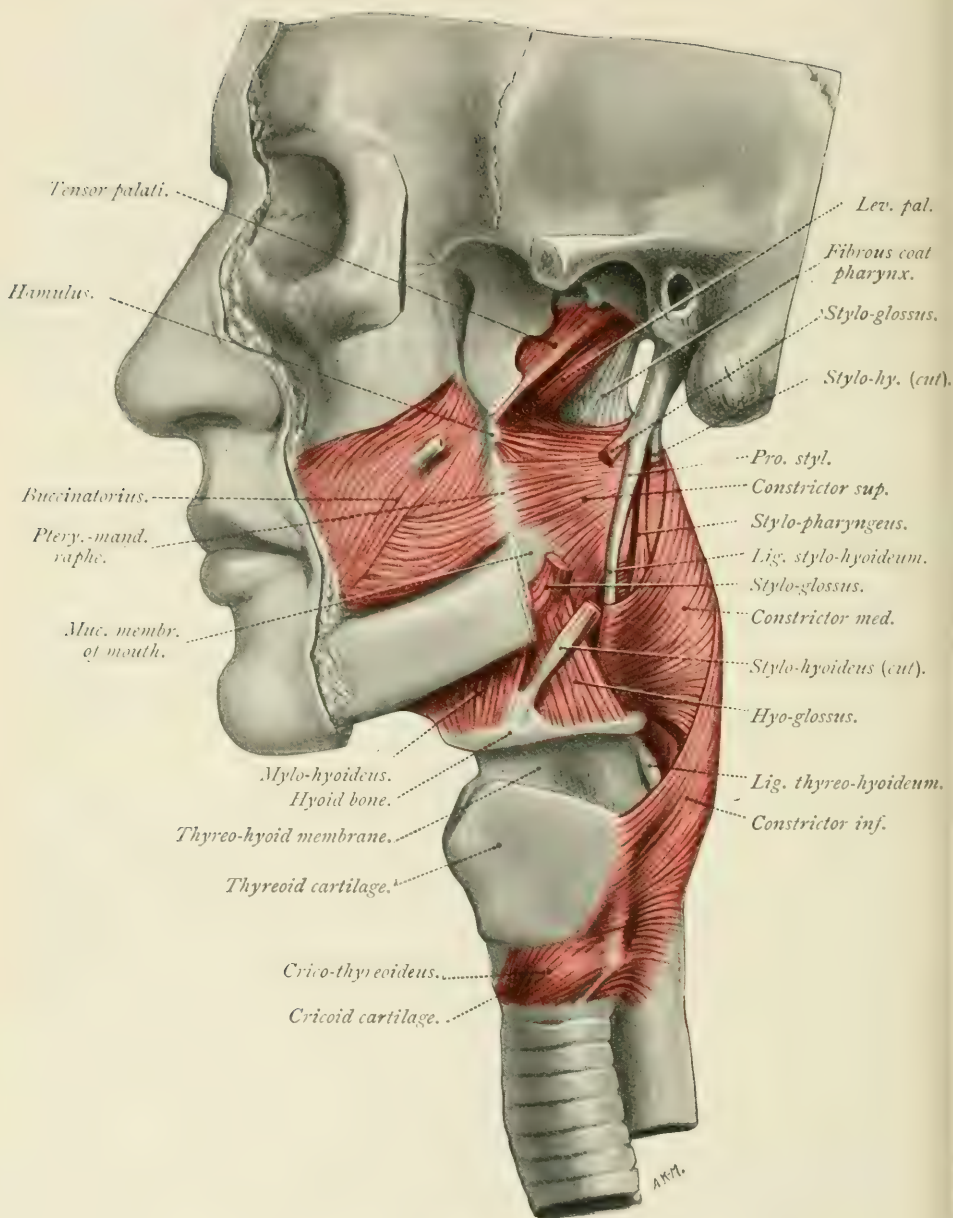


FIG 38. - THE MUSCLES OF THE PHARYNX; LATERAL VIEW.

posteriorly in the fibrous band which fixes the pharynx to the pharyngeal tubercle on the basilar process of the occipital bone. The upper margin curves round the levator palati and the Eustachian tube. The interval between this concave margin and the base of the skull is closed by fibrous membrane. The superior constrictor is sometimes described as consisting of two parts—the *pterygo-bucco-pharyngeus* and the *glosso-pharyngeus*.

The constrictor muscles are invested on the outer surface by a layer of dense connective tissue which is but loosely attached to the prevertebral fascia behind. This layer is stronger above than below, and is prolonged forwards over the lateral surface of the superior constrictor to the pterygo-mandibular ligament, over which it becomes continuous with the membrane covering the buccinator muscle. The fascial layer taken as a whole is, on this account, named the *bucco-pharyngeal fascia*.

Relations.—The constrictors are in contact behind with the upper six cervical vertebrae and the prevertebral muscles. They are related laterally to the great vessels of the neck, the vagus nerve, and the sympathetic. The inferior constrictor is in contact with the thyroid body and sterno-thyroid muscle. The inferior laryngeal nerve and vessels ascend beneath its lower border, and between it and the origin of the middle constrictor the internal laryngeal nerve and vessels pierce the thyreo-hyoid membrane to reach the larynx. The stylo-pharyngeus muscle is at first in contact with the superior constrictor and then descends to the pharynx between the middle and superior constrictors. The latter muscle conceals the palato-pharyngeus and the tonsil.

M. Stylo-pharyngeus (figs. 36, 37, 38). The stylo-pharyngeus, the longest and stoutest of the styloid muscles, arises from the medial surface of the process near its root. It descends downwards and medially, passes under cover of the middle constrictor, where it gradually expands, and being joined by the palato-pharyngeus, ends on the superior and posterior borders of the thyreoid cartilage, and in the lateral wall of the pharynx.

Relations.—The lateral surface of this muscle is, in the upper part of its extent, in contact with the styloid process and the external carotid artery; in the lower, with the middle and inferior constrictors of the pharynx. Medially it rests on the internal carotid artery and superior constrictor, and lower down on the mucous membrane of the pharynx. The glosso-pharyngeal nerve crosses over the muscle in turning forward to the tongue.

Varieties of the Muscles of the Pharynx.—The origin of the superior constrictor may extend along the whole length of the medial pterygoid plate, and the uppermost fibres may be separate. The middle constrictor has been seen arising from the whole length of the stylo-hyoid ligament, and receiving fibres from the body of the hyoid bone, from the tongue, and from the hinder part of the mylo-hyoid ridge on the mandible. The part arising from the greater cornu of the hyoid is sometimes wanting. The inferior constrictor is sometimes more or less united by some fibres with the crico-thyroid, sterno-thyroid, and thyreo-hyoid. A slip from the lateral thyreo-hyoid ligament is of frequent occurrence (*syndesmo-pharyngeus*). The stylo-pharyngeus is often divided into two, sometimes into three slips. A cylindrical muscular slip supplied by the glosso-pharyngeal nerve has been seen arising from the fascia over the ventral border of the sterno-mastoid muscle, and passing over the hypoglossal nerve, and behind the digastric muscle, between the external and internal carotid arteries to the stylo-pharyngeus (Eisler). Supernumerary elevator muscles of the pharynx are not infrequently present, arising from a neighbouring part of the base of the skull, and inserted variably into one or other of the constrictors, or passing between these muscles to the fibrous layer of the pharynx. Their most frequent origin is from the under surface of the petrous temporal in front of the carotid canal, or from the vaginal process of the temporal bone (*petro-pharyngeus*), but they are also found arising from the spine of the sphenoid (*spheno-pharyngeus*), from the basilar process (*occipito-pharyngeus*), or very rarely from the mastoid process (*mastoido-pharyngeus*). Belonging to the same group is the *azygos pharyngis*, a small median slip sometimes present, arising from the pharyngeal tubercle of the occipital bone, and descending to the raphe or the posterior wall of the pharynx.

Nerve Supply.—The stylo-pharyngeus muscle is supplied by the glosso-pharyngeal nerve, the remaining muscles through the pharyngeal plexus from the pharyngeal branch of the vagus, which is said to consist mainly of fibres from the so-called bulbar portion of the accessory nerve. The middle constrictor is generally stated to get a problematic supply from the glosso-pharyngeal, on the strength of observations of Beevor and Horsley on the monkey.

THE MUSCLES OF THE SOFT PALATE

The soft palate (velum palati or palatinum) is a movable curtain, continued backward from the hard palate. It presents posteriorly a free pendulous margin, prolonged in the middle into a conical projection, the *uvula*, and at each side into a prominent curved fold, the *posterior pillar of the fauces* (*arcus pharyngo-palatinus*). This fold runs downwards and backwards on the side wall of the pharynx, while from the base of the uvula and the under surface of the soft palate another fold, the *anterior pillar of the fauces* (*arcus glosso-palatinus*), descends to the tongue. Between the two folds is a recess lodging the tonsil. The constricted passage between the anterior pillars, leading from the mouth to the pharynx, is called the *isthmus of the fauces*. The soft palate consists of two layers of mucous membrane, buccal and pharyngeal respectively, between which are placed a number of muscles in the form of thin sheets, which are fixed to, and by thin tendinous expansions themselves give origin to, a fibrous membrane named the aponeurosis of the palate. The muscles acting on the soft palate are the palato-glossus, the palato-pharyngeus, the muscle of the uvula, the levator palati, and the tensor palati.

M. Palato-glossus, or **Glosso-palatinus**, occupies the palato-glossal fold. Superiorly it is placed below all the other muscles of the palate, and its fibres are continuous with those of its fellow of the opposite side. Inferiorly its fasciculi turn medially, and enter the side of the tongue, where they become continuous with the transverse fibres of that organ.

Behind and continuous with the fibres of this muscle are some thin bundles of muscular fibres which ascend from the side of the tongue, and are lost over the outer surface of the tonsil. They are named *amygdalo-glossus* by Broca. The *palato-glossus* has been seen to exchange fibres with the *hyo-glossus* and superior constrictor of the pharynx.

M. Palato-pharyngeus, or **Pharyngo-palatinus** (fig. 39), occupies the palato-pharyngeal fold. It can be resolved into two layers of fibres. The superficial or upper layer, exposed by removing the pharyngeal mucous membrane from behind, consists of a thin lamella of fibres, often discontinuous, which join those of the opposite side in the middle line. The deep or lower layer is much stronger, and separated from the superficial layer by the muscle of the uvula and the fibres of the levator palati streaming downwards and medially into the palate. The fibres of the deep layer partly meet one another in the middle line, partly take origin from the back of the hard palate and the aponeurosis of the velum. Laterally also a distinct bundle of fibres descending from the lower and anterior part of the cartilage of the Eustachian tube can be demonstrated in the fold of mucous membrane descending from the tube and known as the *salpingo-pharyngeal fold* (*m. salpingo-pharyngeus*, Santorini). The muscle, as it descends in the posterior pillar of the fauces, expands considerably, and its fasciculi mingled with those of the *stylo-pharyngeus* are inserted into the upper and hinder borders of the thyroid cartilage, and into the fibrous layer of the lower part of the pharynx, reaching as far as, or even crossing, the middle line posteriorly.

M. Uvulæ (fig. 39).—This is a paired muscle, developmentally. A muscular slip arises on each side of the median plane, from the aponeurosis of the palate, sometimes also from the posterior nasal spine, and descends into the uvula. The two muscular slips are separated by a slight interval above, but unite in the middle line below. The old name *azygos uvulæ* was given to the muscle on the supposition that it was an unpaired median muscle.

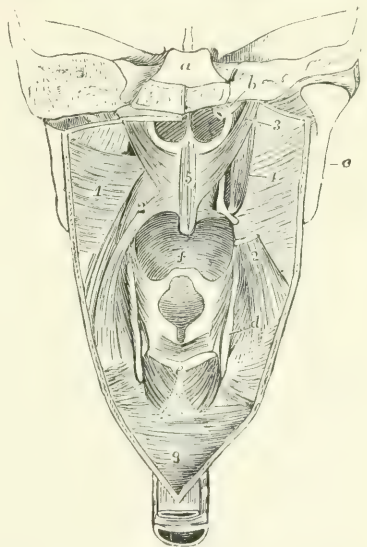
M. Levator Palati, or **Veli Palatini** (figs. 37, 38, 39).—The levator of the soft palate arises by a narrow tendon from the under surface of the petrous portion

of the temporal bone, in front of the orifice of the carotid canal, and from the lower margin of the Eustachian tube. The fasciculi form a rounded belly which underlies the cushion of mucous membrane bounding the opening of the Eustachian tube below and medially, and then passes downwards and forwards into the pharynx, crossing the upper border of the superior constrictor. The muscle becomes flattened as it approaches the middle line, and spreads out in the palate, the upper or fore part being continuous with the aponeurosis, while the larger posterior portion meets the muscle of the other side under cover of the muscle of the uvula.

M. Tensor Palati, or Veli Palatini (figs. 37, 38, 39).—The tensor palati arises from the scaphoid fossa at the root of the medial pterygoid plate, from the spine of the sphenoid, and from the outer limb of the curved cartilaginous plate of the Eustachian tube. Its flattened belly descends perpendicularly on the internal side of the medial pterygoid muscle, and ends in a tendon which, turning round the hamular process, where a synovial bursa smooths its passage, extends horizon-

FIG. 39. —DIAGRAMMATIC VIEW OF THE MUSCLES OF THE SOFT PALATE, ETC., FROM BEHIND. (Allen Thomson.)

The posterior wall of the pharynx has been divided by a vertical incision in the middle line, and the cut edges drawn to the side so as to expose the nasal, buccal, and laryngeal openings. *a* is above the cut surface of the basilar process, and below that are the posterior nares; *b*, cartilage of the right Eustachian tube; *c*, back of the ramus of the lower jaw; *d*, posterior border of the thyroid cartilage; *e*, upper part of the cricoid cartilage; *f*, base of the tongue above the epiglottis; *g*, lower end of the pharynx leading into the gullet; 1, superior constrictor of the pharynx seen from within; 2, palato-pharyngeus; 2', the lower part of the same muscle, on the right side; 3, placed on the internal pterygoid muscle, points to the levator palati; 4, the right circumtensor palati muscle winding round the hamular process; 5, musculus uvulæ; above *e*, the arytenoid, and below it on each side the posterior crico-arytenoid muscle.



tally medianwards, and is inserted into a transverse ridge on the under aspect of the palate bone, and into the aponeurosis of the velum.

Nerves of Supply.—The tensor palati is believed to receive its nerve of supply from the mandibular division of the fifth nerve through the otic ganglion. All the other muscles are probably innervated from the vagal complex, through the pharyngeal plexus.

Actions of the Muscles of the Pharynx and Soft Palate. The effect of the action of the constrictor muscles is to contract the walls of the pharynx upon its contents and convert the cavity into a transverse slit. The hyoid bone and larynx are at the same time carried somewhat upwards as well as backwards in consequence of the oblique direction of the large number of fibres of the middle and lower constrictors. The upper part of the superior constrictor differs from the rest in being placed above the level of the palate so that it cannot act directly on the food. Moreover, its fibres are attached at both ends to parts which are immovable. The effect of its contraction, therefore, is to flatten the sides of this part of the pharynx and approximate the palato-pharyngeal folds. The *stylo-pharyngeus* is the principal elevator of the pharynx and larynx. The *palato-glossi* depress the palate, raise the back of the tongue, and bring together the palato-glossal folds, thus shutting off the cavity of the mouth from that of the pharynx. The *palato-pharyngei* similarly depress the soft palate and raise the pharynx, but their principal action is to bring together the palato-pharyngeal folds, and so separate the nasal and buccal parts of the pharynx. The *muscle of the uvula* raises and shortens the uvula. The action of the *levator palati* is expressed by its name. The *tensor palati* tightens and supports

the soft palate against pressure from below, and against the pull of the depressor muscle. It also opens the orifice of the Eustachian tube in the act of swallowing.

The muscles of the pharynx and soft palate, acting in conjunction with those of the tongue and hyoid bone, are concerned in the act of swallowing. In the first stage of this operation the mylo-hyoid, the stylo-glossus, and the palato-glossus muscles press the tongue against the palate and so force the food backwards through the isthmus of the fauces. At the same time the hyoid bone is raised by its proper elevators, the larynx is carried upwards under it by the thyreo-hyoid and stylo-pharyngeus muscles, and the root of the tongue is drawn backwards by the stylo-glossi. The result is that the epiglottis is pressed down over the superior aperture of the larynx, which is thus protected against the entrance of food. Simultaneously the soft palate is raised and fixed by the levator and tensor palati muscles, and the posterior pillars of the fauces are brought together so as nearly to touch one another (the uvula lying in the interval between them). The passage of food into the naso-pharynx is thus prevented, and the soft palate forms an inclined surface down which the food is guided into the lower part of the pharynx and into the grip of the constrictor muscles. These muscles contract rapidly from above downwards, and force the food into the tube of the gullet below.

Development and Morphology of the Muscles of the Pharynx and Soft Palate.—

Little is known concerning the development of this group of muscles in man. The tensor palati is said to arise in the mandibular arch, the levator palati and the muscle of the uvula in the hyoid arch, while the constrictors, the stylo-pharyngeus, and the palato-glossus come from the third arch. In lower vertebrates Edgeworth shows how the constrictor musculature of the pharynx is a continuation forwards of that of the cesophageal section of the gut, and that it arises like this from the *splanchnic* mesoderm of the head cœlom. It arises from the epithelium of the splanchnocœle independently of the branchial muscle plates, and spreads up on each side round the pharynx medial to the plates until the two lamellæ meet dorsally and entirely surround it. In rabbit embryos Edgeworth describes a similar mode of development for the pharyngeal muscles. The sheets of premuscle tissue appear first in the region of the third branchial arch; then extend forwards to the second and first branchial, and ultimately (in 13 mm. embryos) to the mandibular arch. From the sheets which thus appear on each side and unite in the mid-dorsal line the whole of the muscles of the pharynx and soft palate are formed. The anterior end in the mandibular arch separates off as the tensor palati. This account provides a rational explanation of the supply of the muscles by the bulbar part of the accessory nerve—the tensor palati alone excepted. The stylo-pharyngeus also appears in the splanchnic mesoderm according to Edgeworth, and becomes connected with the developing hyoid cartilage. From its nerve supply it is perhaps rather to be classified with the branchial muscles proper.

The whole of the muscles of the head, including the sterno-mastoid and trapezius, supplied by cranial nerves have now been described, and it will be useful to introduce at this point a table of these muscles arranged in a morphological series.

TABLE II., p. 85.—MUSCLES OF HEAD ARRANGED IN MORPHOLOGICAL SERIES

DEEP LATERAL AND PREVERTEBRAL MUSCLES OF THE NECK

The muscles included in this group are arranged in a lateral and medial series, according to their relation to the issuing ventral roots of the cervical nerves. They represent the lateral part of the ventro-lateral sheet of muscle, the hyoid muscles corresponding, as we have seen, to its medial or rectus column. A great part of this sheet in the neck has acquired connexions with the limb girdle, and the muscles derived from this part will be considered in the next section. Of the remaining muscles a lateral series includes the scalenus medius and posterior; a medial group comprises the scalenus anterior and the prevertebral muscles, the latter coming from the upper four or five, the former from the fifth to the seventh myotomes.

From the topographical point of view the muscles are divided into a lateral or scalene group, and a prevertebral group of muscles.

The scapular muscles are strong muscular columns, which are usually three in number, but sometimes only two. All of them are subdivided above into musculo-tendinous slips, corresponding in number with their attachments to the vertebræ.

	Pre-Mandib.	Mandib.	Hyoid.	First Branchial.	Second and Third Branchial.	Occipital.	Cervical.
Medial Series of Nerves.	Third Nerve.	Fourth Nerve.	Sixth Nerve.			Twelfth Nerve.	1, 2, and 3.
Dorsal mesoderm	Rectus sup. " inf. " med. Obliq. inf. Lev. palp. sup.	Obliquus sup.	Rectus lat.	...	...	Muscles of tongue. Hypo-branchial muscles.	Hyoid muscles.
Lateral Series of Nerves.		Fifth Nerve.	Seventh Nerve.	Ninth Nerve.	Tenth and Eleventh (Vago-Acc.).		
Branchial mesoderm	Somatic muscles ...	Masseter. Temporal. Ptery. ext. " int. Mylo-hyoid. Digastric ant. Tensor tym. Tensor pal.	Platysma. Facial muscles. Scalp muscles. Stylo-hyoid. Digastric post. Stapedius.	Stylo-pharyn.	Trapezius. Sterno-mastoideus.	...	...
	Visceral muscles ..	...	...	...	Constr. inf. " med. " sup. Palato-pharyn. Lev. palati. M. uvulæ. Palato-glossus. Muscles of larynx.	...	...

M. Scalenus Anterior (fig. 40).—The anterior scalene muscle is attached superiorly to the costal processes of the third, fourth, fifth, and sixth cervical vertebræ. The slips of origin are not confined to the anterior or costal tubercles, but extend to the bars joining the costal with the transverse processes. The muscle is inserted by a thick flattened tendon to the scalene tubercle upon the first rib.

M. Scalenus Medius (fig. 40).—The middle scalene muscle arises by a succession of slips from the transverse processes of the third to the seventh cervical vertebræ. These attachments are invariable, but in addition slips may arise from the axis and atlas vertebræ. Each slip springs (Le Double, Poirier, Eisler) from the bar bounding the intervertebral notch, and extends backwards to the transverse tubercle or forwards to the costal tubercle. Inferiorly the muscle is attached to a rough impression on the first rib, reaching from the tuberosity to the groove for the subclavian artery. Sometimes the insertion spreads to the upper border of the second rib and fascia of the first intercostal space. It may even in some cases extend to the third rib.

According to Eisler the muscle arises frequently, if not constantly, by two sets of slips, a dorsal and a ventral, between which is placed a "long intertransverse muscle" intimately bound up with the proper scalene slips. This is sometimes described as a variety of the muscle in which the fasciculi do not reach the ribs, but end on the cervical transverse processes (*transversus cervicis medius* or *anticus*). Poirier describes the posterior scalenus muscle as having two heads; the deep head corresponds to the dorsal part of the scalenus medius of Eisler. The accessory slips attached to the transverse process of the axis or of the atlas vertebræ are not, according to the same authority, properly scalene slips, but are long intertransverse muscles inserted on the next succeeding slip of the scalenus medius.

M. Scalenus Posterior (fig. 34).—This is the smallest of the three scaleni, and is not infrequently absent. It arises by slips from the posterior tubercles of the transverse processes of two or three cervical vertebræ, normally the fifth and sixth. Turning somewhat forwards round the scalenus medius it ends in an aponeurotic tendon which is attached to the outer surface of the second rib, lateral to the serratus posterior superior. The insertion may extend to the third, or even to the fourth rib.

Relations.—The mass formed by the scaleni muscles, narrow at its origin from the transverse processes, broadens below on the first rib round the superior aperture of the thorax and the pleural cupola. Under cover of the sterno-mastoid at their origins, the muscles appear below in the posterior triangle of the neck, where, covered by the deep fascia, they form the floor of the supraclavicular space, and are crossed obliquely by the posterior belly of the omo-hyoid muscle. The *scalenus anterior* is entirely under cover of the sterno-mastoid, but for a small part of its anterior surface exposed below above the clavicle. It is related medially to the longus capitis, which arises from the same costal processes, and behind to the scalenus medius. From this muscle it is separated by an elongated triangular cleft, through which the subclavian artery and the nerves of the brachial plexus pass to cross over the first rib. These structures, therefore, lie behind the scalenus anterior and in front of the scalenus medius. The *scalenus medius* is in contact dorsally and laterally with the levator scapulæ at its upper part, and with the scalenus posterior below, the latter muscle intervening between it and the ilio-costalis cervicis behind. The subclavian vein is placed in front of the scalenus anterior at its insertion, and separates it from the clavicle, while the internal jugular vein lies medial and anterior to it as it descends in the neck. The phrenic nerve lies upon the scalenus anterior as it enters the thorax.

Nerves.—The scaleni muscles are supplied by short twigs which come off the adjacent vertebral branches of the spinal nerves as they emerge from the intervals between the costal and transverse processes. The scalenus anterior receives its twigs from C 5, 6, 7, and 8 (when there is a slip from the seventh cervical vertebræ); the medius from C (4) 5, 6, 7, 8; the posterior from C (7) 8.

Varieties.—The scaleni muscles are subject to a considerable amount of variation, both in the number of their points of attachment and in the arrangement of their fibres. The scalenus

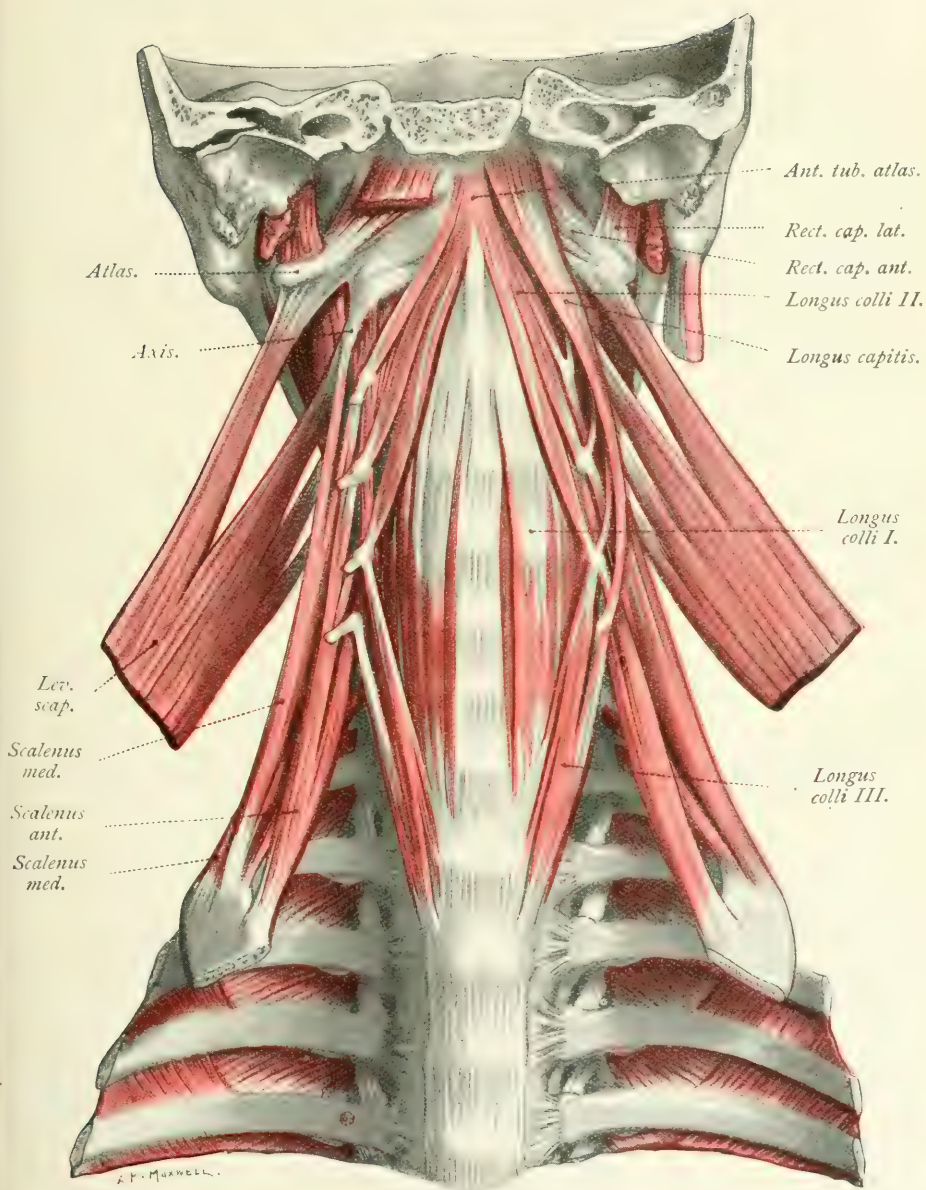


FIG. 40.—THE PREVERTEBRAL GROUP OF MUSCLES.

Longus colli I.—Vertical portion.
 " II.—Upper oblique portion.
 " III.—Lower oblique portion.

anterior is sometimes inserted behind the subclavian artery; or is split into two portions for the artery to pass between them. In such a case the muscle has been seen pierced by the eighth nerve dorsal to the artery. Bundles are sometimes given off from the scalenus anterior to the scalenus medius, or *vice versa*. The anterior muscle is frequently closely bound up with the anterior intertransverse muscles, exchange of slips taking place between them. The same is the case with the longus capitis (rectus cap. ant. major). The *M. scalenus pleuralis* (Sibson) or *minimus* (Albinus) is a frequent variation. When present it arises from the transverse process of the seventh cervical vertebrae (sometimes also from that of the sixth), and spreads out to be attached to the inner border of the first rib and the fascia supporting the cervical dome of the pleura. When absent the muscle is replaced by a fibrous band (Sibson's fascia, lig. costo-pleuro-vertebralis, Zuckerkandl). The scalene group of muscles as a whole corresponds to the intercostal muscles of the thorax. Owing to the absence of free ribs the elements have merged as in the abdominal wall, but there is no distinct division into layers. The relations of the issuing segmental nerves suggest that the scalenus anterior corresponds with the inner *transverse layer* in the rest of the trunk. This homology is here put forward (see fig. 15, p. 22), but it is right to say that Forster in a memoir on the group published recently states that the relation of the nerves is not absolutely constant, either in man or lower mammals.

Prevertebral Group of Muscles.—This group includes a number of muscles which are formed by the growth and spread of the upper four or five cervical myotomes on to the front of the vertebrae. The separate processes from the myotomes fuse to form a continuous column out of which, by a process of cleavage, the several muscles are evolved. The superficial fibres are not segmentally arranged, but pass over several vertebrae, and give rise to the *longus capitis* and *longus colli* muscles. The deeper bundles retain their segmental arrangement, and extend between the transverse processes as *anterior intertransverse muscles*, the uppermost of the series finding attachment to the occipital bone as the *rectus capitis anterior*. Between the transverse process of the atlas and the condylar process of the occipital bone a muscular slip named *rectus capitis lateralis* represents the first of a series of *lateral intertransverse muscles* (Eisler), which also belong to this group developmentally or by nerve supply, but are intimately united with a *dorsal intertransverse series* supplied by the dorsal divisions of the spinal nerves, and therefore to be included with the dorsal musculature.

The superficial layer of the prevertebral musculature is divided for descriptive purposes into two parts, one confined to the spine, the other inserted into the occipital bone.

M. Longus Capitis (fig. 40).—The longus capitis arises by tendinous slips from the costal tubercles of the third, fourth, fifth, and sixth cervical vertebrae. The slips, becoming shorter from below upwards, unite to form a single belly which, converging on its fellow of the opposite side, is inserted into the basilar process of the occipital bone on a curved impression a little in front of the foramen magnum. The muscle frequently receives an accessory head from the lower oblique portion of the longus colli, and when this is isolated the longus capitis may appear to spring from the thoracic vertebrae. The muscle shows as a rule a tendinous intersection on its anterior aspect, which divides it into two parts but does not extend through the whole thickness of the muscle.

Relations.—The muscle rests on the vertebrae, parts of the longus colli and rectus capitis anterior. Its anterior surface supports the pharynx, vagus, and sympathetic nerves, and the great vessels of the neck.

Varieties.—The longus capitis is sometimes inseparably united with the longus colli. A muscular slip—atlanto-basilar or axio-basilar—sometimes occurs along the medial margin of the longus capitis.

M. Longus Colli (fig. 40).—The longus colli muscle rests on the front of the vertebral column from the atlas to the third thoracic vertebrae. It consists

of three sets of fasciculi, of which one is vertical and two are oblique. (a) The *vertical* part arises by a series of flattened muscular and tendinous processes from the bodies of the lower two cervical and upper two or three thoracic vertebræ, and along its lateral border it receives reinforcing slips from the costal processes of the lower three or four cervical vertebræ. These vertical fasciculi are inserted into the bodies of the second, third, and fourth cervical vertebræ. (b) The *lower oblique* part, the smallest of the three, takes origin in common with the vertical part from the bodies of the upper thoracic vertebræ, and is inserted by narrow tendinous slips into the costal tubercles of the fifth and sixth cervical vertebræ. (c) The *upper oblique* part arises by separate slips from the costal tubercles of the third, fourth, and fifth vertebræ, and is inserted into the lateral part of the tubercle on the ventral arch of the atlas, becoming connected also with the upper end of the vertical part.

Relations.—By its anterior surface the longus colli is in contact with the pharynx and œsophagus, the great vessels of the neck contained in their sheath, the sympathetic and recurrent laryngeal nerves, and the inferior thyreoid artery.

M. Rectus Capitis Anterior (fig. 40).—This is a small flat muscle partly covered by the longus capitis. It represents an anterior intertransverse muscle. It arises from the root of the transverse process of the atlas, and is inserted into the basilar process of the occipital bone, between the foramen magnum and the longus capitis muscle.

It may be absent or reduced to a few bundles. It may fail to reach the occipital bone, being attached to the occipito-atlantal ligament. A medial portion is sometimes separated from the rest (*rectus capitis minimus*).

The **anterior intertransverse muscles** (fig. 40, unlabelled) will be described later with those of the other parts of the vertebral column. On morphological grounds, as already stated, they fall into the prevertebral group.

It may be stated here that frequently muscular slips are met with which lie immediately lateral to the anterior intertransverse muscles, but extend over several transverse processes. The name *intertransversalis anterior longus* or *transversalis cervicis anticus* has been given to such muscular bundles. They may be considered as slips intermediate between the long superficial bundles and the deep segmental bundles of the prevertebral musculature. In the same way long intertransverse slips are not infrequently found more laterally placed, and connected with the deep lateral muscles (see p. 86).

M. Rectus Capitis Lateralis (fig. 40).—This is a short thick muscle arising from the upper and fore part of the enlarged extremity of the transverse process of the atlas, and inserted into the rough under surface of the condylar portion of the occipital bone. It represents the lateral intertransverse muscle of the space between the transverse process of the atlas and the occipital bone.

An accessory bundle arising from the transverse process of the axis vertebra has been observed (*rectus lateralis longus*).

Nerves.—All the prevertebral muscles are supplied from the ventral branches of the cervical nerves by short twigs arising close to the exit of the branch. The longus capitis receives fibres from C 1 to C 4 (C 5); the longus colli from C 2 to C 5; the small branch for each anterior intertransverse muscle comes off the trunk in front of which it lies close to its origin, or from a branch to one of the other prevertebral muscles; that for the lateral intertransverse slip is given off from the ventral trunk near its root, but may be bound up with the dorsal branch for a certain distance (Eisler). The nerves for the rectus anterior and rectus lateralis come from the ventral trunk of the first cervical nerve.

THE MUSCLES AND FASCIÆ OF THE UPPER LIMB

A certain number of muscles situated superficially on the trunk both ventrally and dorsally pass to the bones of the pectoral girdle and to the humerus, so as to attach the upper limb to the body. All these muscles, the trapezius excepted, belong to the ventro-lateral sheet of musculature, directly or indirectly. Moreover, they are actually or theoretically derivatives of the lower cervical myotomes, and therefore fall into their natural place after the muscles of the neck. Most of the muscles have shifted their position during development, and some have extended far away from their original seat of origin. They come therefore to overlap or overlies muscles proper to the trunk and of quite different origin. The great spread of muscles, such as the pectoralis major and latissimus dorsi, is to be correlated with the freedom of movement of the shoulder-joint, especially great in man and apes when the limb is used solely as a grasping organ.

The group includes the trapezius, which has already been described (p. 67), the latissimus dorsi, the rhomboids, the levator scapulæ, the serratus anterior (magnus), the two pectorals, and the subclavius.

The rhomboids, levator scapulæ, and serratus magnus all arise in the human embryo from a single premuscle mass in the cervical region, while the latissimus dorsi, the pectorals, and probably also the subclavius, take origin in the limb bud itself and spread thence secondarily over the trunk. The general arrangement of these muscles is determined in all mammals by the mobility of the pectoral girdle. The details of structure, size, and relative development vary in the different orders according to the mechanism of the fore limb, and the uses to which it is put. In man and the primates generally the special features are impressed on the muscles according to the part played by the movements of the girdle in extending the scope of the movements of the arm as a grasping organ.

DORSAL GROUP OF MUSCLES EXTENDING BETWEEN TRUNK AND LIMB

Fascia.—The deep fascia of the back forms a fairly dense layer of matted fibres closely investing the superficial muscles to which it furnishes sheaths. At the lateral margins of the trapezius and latissimus dorsi it is continuous with the deep fasciæ of the neck, axilla, thorax, and abdomen. It turns round under the edge of these muscles so as to complete their sheaths, and separate them from the subjacent layer of muscles. It is attached to the skeleton along the line of the spines of the vertebræ, to the superior curved line of the occipital bone, the spine of the scapula, and iliac crest. The upper portion of this sheath is described with the cervical fascia, while the *lumbar fascia* with the strong, flat, shining tendinous lamella to which the latissimus and other muscles are attached posteriorly, as well as its forward deep extension in the *vertebral fascia*, will be most conveniently described with the trunk muscles.

The general trend of the fibres of the fascia over the latissimus dorsi is latero-caudal. A distinct layer with its fibres directed nearly vertically to the lateral border of the trapezius passes below that muscle on the latissimus to reach the thoracic spines (5 to 8), and to merge with an aponeurotic lamellæ connected with the anterior border of the last-named muscle.

Above the iliac crest the fascia passes over from the surface of the latissimus on to the surface of the external oblique muscle, and bridges over the triangular interval between the two muscles (triangle of Petit). In the interval it is attached to the fascia of the subjacent internal oblique muscle.

M. Latissimus Dorsi (figs. 41, 42, 59, 68).—The latissimus dorsi is by development a limb muscle. It springs from the hinder part of the premuscle

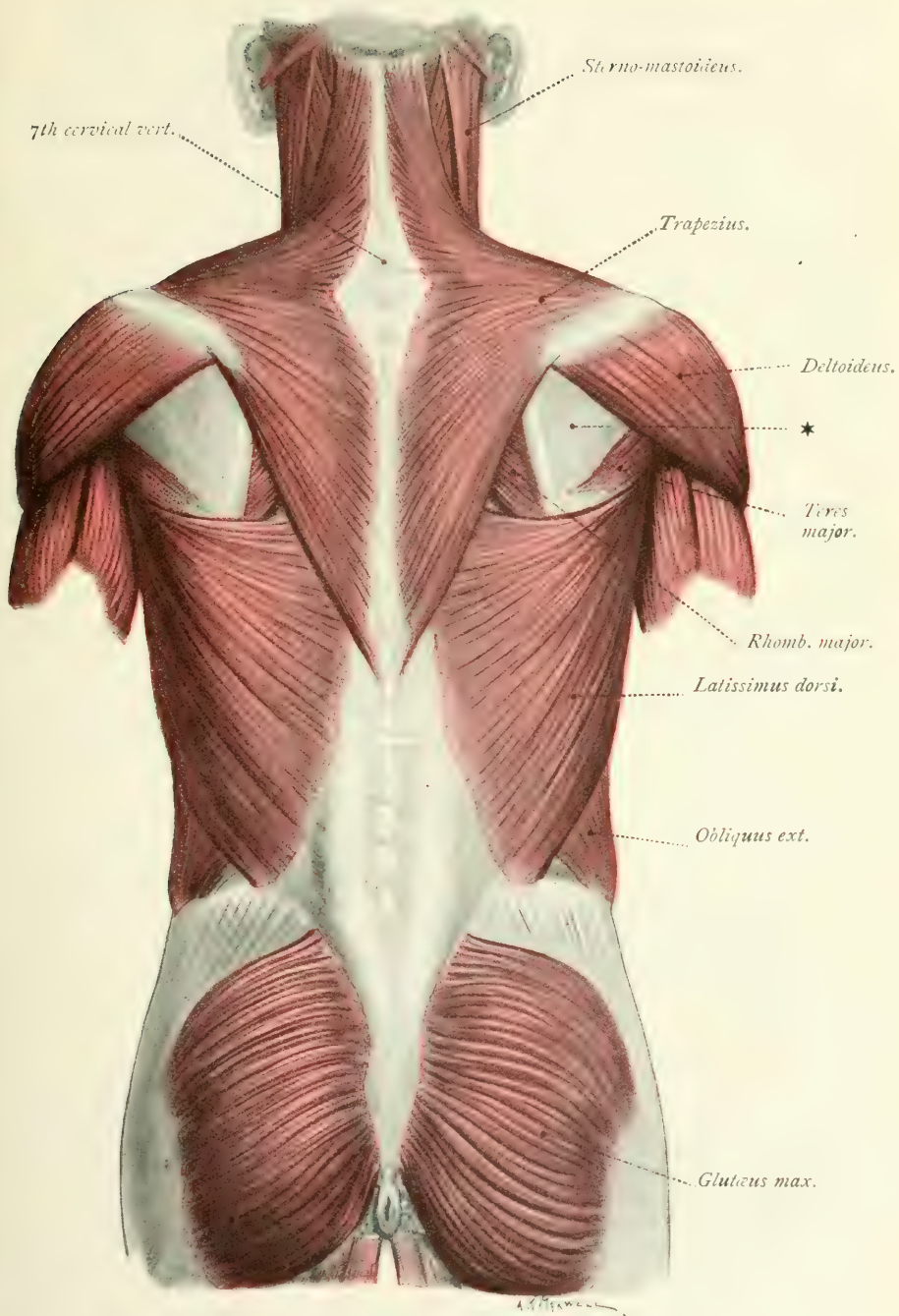


FIG. 41.—MUSCLES OF BACK, FIRST LAYER.

* Fascia covering infraspinatus muscle.

mass at the root of the arm bud, and subsequently spreads backwards over the trunk to obtain attachments to the spines of the vertebræ, the ribs, and the iliac crest. The muscle thus has a vertebral, an iliac, and a costal origin.

The *vertebral attachment* is by means of tendinous fibres springing from the lower six or seven thoracic, the lumbar and the sacral spines. Below the trapezius these fibres, merged with those of the serratus posterior inferior and with the proper fascial fibres, form a strong shining aponeurosis, which covers the mass of the dorsal musculature, and is attached to the lumbar and sacral spines and back part of the iliac crest. The *iliac origin* also consists of short tendinous fibres which are attached to the outer lip of the iliac crest lateral to the lumbar aponeurosis, and as far as the middle of the crest. The *costal origin* consists of a series of narrow fleshy slips springing from the last three or four ribs which interdigitate with the lower attachments of the external oblique muscle of the abdomen.

The uppermost fibres of the muscle are the shortest, and pass almost horizontally outwards over the inferior angle of the scapula, from which they often receive a small slip of fleshy fibres. The lower fibres are longer, and become progressively more oblique until those arising from the ribs ascend almost vertically. By this convergence the fibres of the muscle come to form a narrow band of some thickness, which, accompanying the teres major towards the axilla, winds round the lateral and lower border of that muscle so as finally to be placed in front of it. It terminates in a flat tendon about 35 mm. in breadth which, closely applied to that of the teres major, is mainly attached to a roughness which extends obliquely across the floor of the bicipital (intertubercular) groove, but also proximally into the medial lip of the groove, and distally to the lateral lip where the fibres mingle with those of the pectoralis major. The tendon appears in the thickness of the muscle and receives muscle fibres on both faces. From the twisting of the muscle on itself the ventral surface of the tendon is continuous with the dorsal surface of the rest of the muscle. The tendon is adherent to that of the teres major along its distal border, by some loose fibrous tissue, but above it is separated from it previous to its insertion by a synovial bursa. As a rule the distal border of the tendon is placed a short distance above the corresponding margin of the teres major, but not infrequently the borders of the two tendons are on the same level, and are bound closely to one another so as to close in the space between them occupied by the bursa. There is a second bursa in front of the tendon. From the distal border of the tendon an expansion of some strength extends downwards to the fascia of the upper arm, over the medial face of the scapular head of the triceps. A connexion is often to be traced with the medial intermuscular septum.

Relations.—The latissimus dorsi is subcutaneous except at its origin from the thoracic vertebræ, where it is covered by the trapezius, and at its insertion where it is crossed by the axillary vessels and the nerves of the brachial plexus. It rests on the rhomboideus major and the infraspinatus, on the teres major, serratus posterior inferior, vertebral aponeurosis, lower ribs, and external and internal intercostal muscles.

Between the adjacent borders of the latissimus dorsi, trapezius, and rhomboideus major there is left, when the scapula is drawn forwards, a triangular area in which a portion of one or two ribs and of an intercostal space become superficial; this may be taken advantage of for the purpose of auscultation.

Nerve of Supply.—The nerve of the latissimus comes from the posterior trunk of the brachial plexus, and receives fibres from the sixth to eighth cervical nerves, but chiefly from the seventh. It runs over the subscapularis and teres major and breaks up into several branches which sink into the substance of the muscle, along a line parallel to the free border and a short distance medial to it. The branches to the vertebral part of the muscle are connected by loops with one another, but not with the branch to the ilio-costal part, indicating a possibility that the muscle is composed of two morphologically distinct portions (Eisler).

Varieties and Morphology.—The number of thoracic vertebræ to which the latissimus dorsi is attached varies from four to seven or eight. In some cases the first slip comes from the first lumbar vertebra. The number of costal slips is also variable, being frequently diminished and more rarely increased. The iliac origin may be more extensive, may be reduced or entirely wanting. Cases have been described in which the vertebral portion of the muscle is absent. These variations are explained by the history of the muscle. The most recently acquired features show variability. The latissimus dorsi has undergone a greater extension backwards than in the lower primates, due presumably to the greater freedom of the arm and the assumption of the erect posture. The extension to the iliac crest first occurs in the higher Simiidae and reaches its maximum among them, but in man there is a further extension forwards on the spine. With the iliac extension there appears to have been a reduction of the costal portion, because in the Gibbon, while there is no iliac origin, there are a greater number of costal slips than in the other Simiidae and man. A rare variety met with also in the Simiidae, named *rhomboideus minimus*, represents a detached part of the latissimus. It comes from the sixth thoracic spine, crosses the inferior angle of the scapula, and merges with the teres major. In addition to the bundle from the angle of the scapula there occasionally occur separate bundles which fall short of the common aponeurosis and are attached to the deep fascia of the back. A muscular bundle has been described passing from the inferior angle of the scapula upwards and laterally, to merge with the deltoid at its dorsal border. All these varieties readily find explanation when the seat of origin of the muscle and the manner in which it spreads over the trunk in the course of development are considered. A splitting up of the muscle into separate bundles has been observed, and occasionally it has been seen separated into two portions, vertebral and ilio-costal. This condition is normal in some lower mammals, and it has been suggested that the latissimus dorsi is compounded of two distinct muscles, the *dorso-humeralis* and *thoraco-scapularis* of Urodelas and Sauropsida (Eisler, 1895).

Isolated bundles of muscular fibres derived from the latissimus are sometimes seen to pass from the muscle near its insertion across the axilla, where they terminate in the fascia or extend over the great vessels and nerves to merge with the tendon of the greater pectoral, the coracobrachialis, the biceps, the capsule of the joint or coracoid process. These form one variety of the so-called *axillary arches*, distinguished by their nerve supply (the long subscapular nerve) from very similar slips supplied by the anterior thoracic nerve. In all such instances the explanation is not that elements of the latissimus, which is a purely dorsal muscle, have extended their insertions and invaded the domain of the pectoral muscles, but that marginal bundles of the muscle have merged with remnants of the panniculus carnosus which are attached to the parts named (see under Pectoral Muscles). From the lower border of the tendon a muscular slip is occasionally given downwards to the long head of the triceps, to the fascia, or to the medial intermuscular septum of the arm, corresponding to the *dorso-epitrochlearis* muscle of apes and many other mammals. The fibrous slip in the same situation described above may perhaps be considered as a vestige of the muscle. In lower mammals this muscle is sometimes extended to the forearm, and serves to bring back the limb from the forward position. In the anthropoids and in man this action is not required, and the muscle disappears.

The levator scapulæ and the rhomboid muscles placed under the trapezius constitute the second layer of the muscles of the back. As stated above, they and the serratus magnus (anterior) arise from a common rudiment which at first lies in the cervical region ventral to the myotomes, and is derived in all probability from material supplied by them.

M. Levator Scapulæ (figs. 34, 35, 40, 42, 59, 60, 61).—The levator scapulæ arises by tendinous slips from the posterior tubercles of the transverse processes of the four upper cervical vertebræ, between the attachments of the splenius and scaleni muscles. The four slips merge to form an elongated fleshy mass thickest at its lower end, which is inserted into the vertebral border of the scapula from the medial angle to the root of the spine. The first and second slips are the strongest and most constant. The insertion is by short tendinous fibres which appear first on the dorsal face of the muscle. Often some bundles of the muscle pass to end on the fascia over the supraspinatus.

Relations.—The levator scapulæ is covered at its origin by the sterno-mastoid, and at its insertion by the trapezius. Between these it is superficial in the posterior triangle of the neck. It lies over the splenius cervicis, ilio-costalis cervicis posterior scapular artery, and the first two ribs.

Nerves of Supply.—The levator scapulae is supplied by the ventral divisions of the third, fourth, and fifth cervical nerves. The fibres reach the muscle either directly in branches from the main nerves or in the nerve to the rhomboids (dorsal scapular nerve). Some authorities trace fibres from the second cervical nerve, while others limit the supply to the fourth and fifth nerves.

Varieties.—In most lower mammals the levator scapulae is continuous with the serratus magnus. In the higher primates and man there is a gap between the two muscles due to the dropping out of slips from the lower cervical transverse processes. In rare instances this missing part of the sheet is present, and the levator is connected with the serratus. On the other hand, the number of slips is often reduced. As reduction is more common than increase, and the first two slips are the most constant, the reduction has apparently taken place from behind forwards. The original connexion with the serratus is further indicated by the occasional presence of separate slips connected with that muscle on its lateral or its costal surface. The single slips of origin may remain separate from one another. Additional slips of origin may be present from the mastoid process or the occipital bone, from the trapezius or longissimus cervicis, from the fascia over the splenius muscle, from the under surface of the rhomboid muscle, and even from the first or the second rib, or from both.

The insertion is occasionally extended backwards between the rhomboid and serratus magnus muscles on the vertebral border of the scapula to the spine of the scapula, or in rare cases to the first and second ribs, while separate bundles may connect the muscle with the serratus magnus, as already mentioned, or the fascia beneath it, or with the fascia over the serratus posterior superior. A total absence of the muscle has been noted.

M. Rhomboideus Minor (figs. 42, 59).—Many anatomists do not separate the rhomboid sheet into two portions. The cranial portion, amounting to about one-fifth, is imperfectly separated from the remaining four-fifths by a fibrous intersection and a perforating branch of the posterior scapular artery, and to this is given the name *rhomboideus minor*. It forms a narrow band which arises from the ligamentum nuchae as high as the fifth cervical spine, from the spinous process of the seventh cervical and the first thoracic vertebrae. It inclines downwards and outwards, to be inserted to the vertebral border of the scapula opposite the triangular area at the root of the spine.

M. Rhomboideus Major (figs. 42, 59), comprising about the caudal four-fifths of the rhomboid sheet, arises from the spinous processes of the first four or five thoracic vertebrae and the supraspinous ligament. It is inserted into that part of the vertebral border of the scapula which is included between the spine and the inferior angle. The muscle arises by tendinous fibres which form an aponeurosis, narrow above but broadening below. The muscular fibres of the rhomboideus minor run parallel to one another, but those of the rhomboid major mainly converge towards the inferior angle of the scapula. This muscle must apparently, therefore, mainly act on the lower angle. In a certain proportion of cases the fibres end on a fibrous arch or band which is loosely fixed to the vertebral border, but firmly attached to near the inferior angle.

Balli (1906) gives the following details regarding the attachment of the rhomboideus major to the scapula. In 54 per cent. of cases the upper and middle fibres are attached by weak tendinous fibres to the vertebral border below the rhomboideus minor, the lower fibres by a strong tendon to near the inferior angle. In 21 per cent. of cases the insertion is by a fibrous arch attached weakly above to the vertebral border below the rhomboideus minor, but strongly below on the inferior angle, where it receives the chief mass of the fibres. In some instances (6 per cent.) the arch is replaced by two or three smaller arches. In 19 per cent. of cases all the fibres converge on the inferior angle so that the muscle is triangular, not rhomboidal.

Relations.—The greater part of the rhomboid muscles is covered by the trapezius, a small angular portion only of the larger muscle being subcutaneous in the interval between the trapezius and the latissimus dorsi. The extent of this portion varies with the position of the scapula, being increased when the arm is raised from the side. The rhomboid muscles cover the greater part of the serratus posterior superior, and the posterior scapular artery descends on their deep surface.

Nerve of Supply.—Both rhomboids are supplied by the dorsal scapular nerve, which comes mainly from the fifth cervical nerve, but according to some may also receive fibres from the fourth or the sixth. After giving fibres to the levator scapulae the nerve passes below the rhomboideus

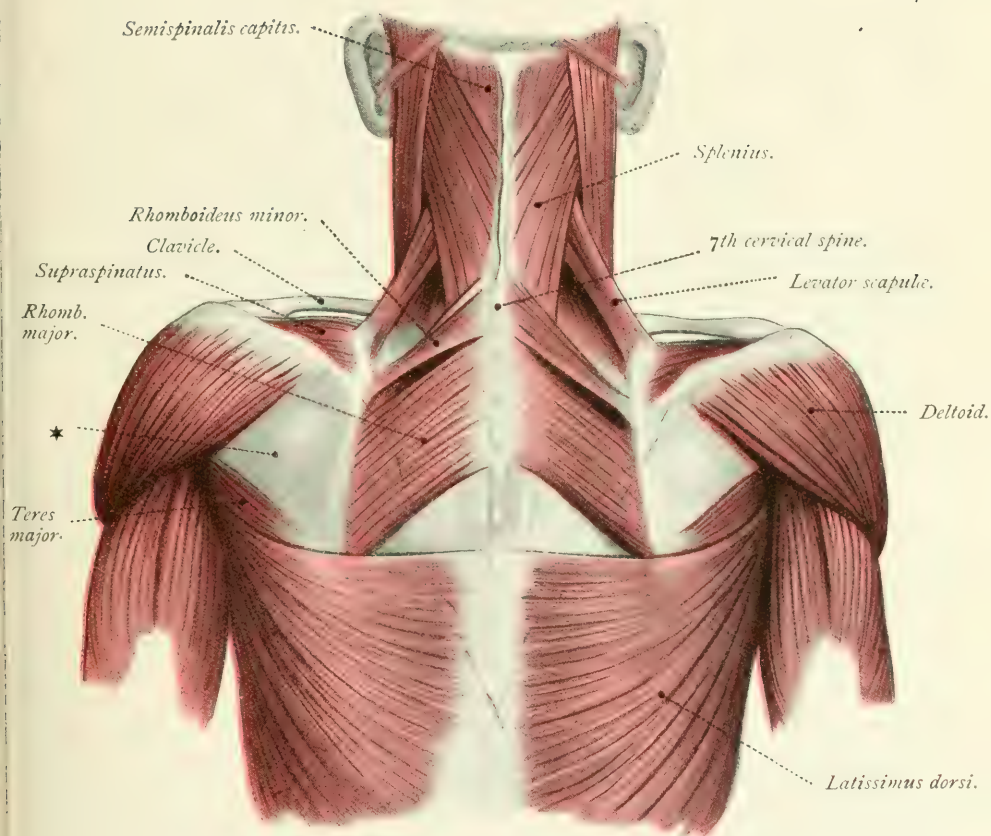


FIG. 42.—MUSCLES OF THE BACK; THE SECOND LAYER IS EXPOSED BY THE REMOVAL OF THE TRAPEZIUS.

★ *Fascia of infraspinatus muscle.*

minor in the angle between it and the levator, and forms a plexus on the deep surface of the muscles, from which branches are given off in succession to enter the muscular substance, in which again the fine branches are bound together into loops by connecting strands.

Variations.—The rhomboid sheet may extend beyond the normal limits both in the cranial and caudal direction. In some instances the caudal border may meet the cranial border of the latissimus dorsi, if with a caudal extension of the rhomboideus major there be associated a cranial extension of the latissimus. The rhomboideus minor may be broken up into separate bundles, and the same condition may affect the back part of the major muscle. A deep lamella may be present, taking the form of a slip of muscular fibres arising with the cranial part of the sheet but crossing obliquely the main mass of bundles to reach the inferior angle of the scapula. Slips from the tendinous insertion may sweep over into the fascia of the infraspinatus muscle, or into the teres major or scapular origin of the latissimus dorsi. An additional muscle has been observed running close to the upper border of the minor, from the scapula to the occipital bone, and has been named the *rhomboideus occipitalis* or *capitis*, after a similar muscle occurring in some animals, or otherwise *occipito-scapularis*. In a modified form this accessory muscle may be present as a slip arising from the transverse process of the atlas or the fascia over the splenius capitis, and attached to the vertebral border of the scapula; on the other hand, the caudal attachment may be to the surface of the serratus posterior superior instead of to the scapula. The rhomboid sheet of muscle, as already stated, is intimately associated in its development with the levator scapulæ and serratus magnus muscles. Like the trapezius and latissimus dorsi, it becomes secondarily extended over the dorsal group of muscles. It is clearly derived from one or more cervical myotomes, and the course of its nerve indicates that it has been displaced backwards and dorsally. It acquires a connexion with the scapula and later with the spinous processes of the vertebræ, spreading over the muscle mass originally dorsal to it. The descent of the scapula in ontogeny leads to a further backward displacement, and to the characteristic obliquity of the muscular bundles.

VENTRAL GROUP OF MUSCLES BETWEEN TRUNK AND LIMB

Fascia.—The deep fascial sheet in the pectoral region is for the most part thin and unimportant. Covering the pectoralis major it passes upwards under the slips of the platysma which descend over the clavicle. It is attached partly to the bone and partly merges with the fascia of the neck under that muscle. Medially it is attached to the front of the sternum. Laterally it is continuous with the fascia over the deltoid and fascia of the arm, showing a tendency to resolve itself into layers which fuse over the insertion of the great pectoral muscle into a denser, stronger layer continued on the front of the arm. The fibres are disposed mainly in a transverse direction, in keeping with stresses set up by contraction of the muscles and by outward rotation of the arm. Between the pectoralis major and deltoid the fascia covers over the fascial interval occupied by the cephalic vein and its accompanying artery, and is here continuous with the deeper fascial layer. The fascia is further continuous round the lateral border of the pectoralis major with the axillary fascia and with the layer next to be described.

Below the pectoralis major and separated from it by an areolar layer in which the anterior thoracic vessels and nerves run, is a deep, strong, fascial layer of some importance. Above the pectoralis minor in the space between it and the clavicle, this fascial layer is named the *costo-coracoid membrane* (fig. 43). This membrane is attached superiorly to the clavicle in two lamellæ which ensheath the subclavius muscle. It is blended on its deep aspect with the front of the sheath of the axillary vessels, derived from the deep cervical fascia. The lower margin of the sheath of the subclavius forms a strong tendinous band, sometimes termed the *costo-coracoid ligament*, attached laterally to the medial border and under surface of the coracoid process, and medially to the first rib and its cartilage at the origin of the subclavius muscle. This band bounds superiorly an opening in the fascia, filled with a looser or cribriform layer, for the anterior thoracic vessels and nerves and the cephalic vein.

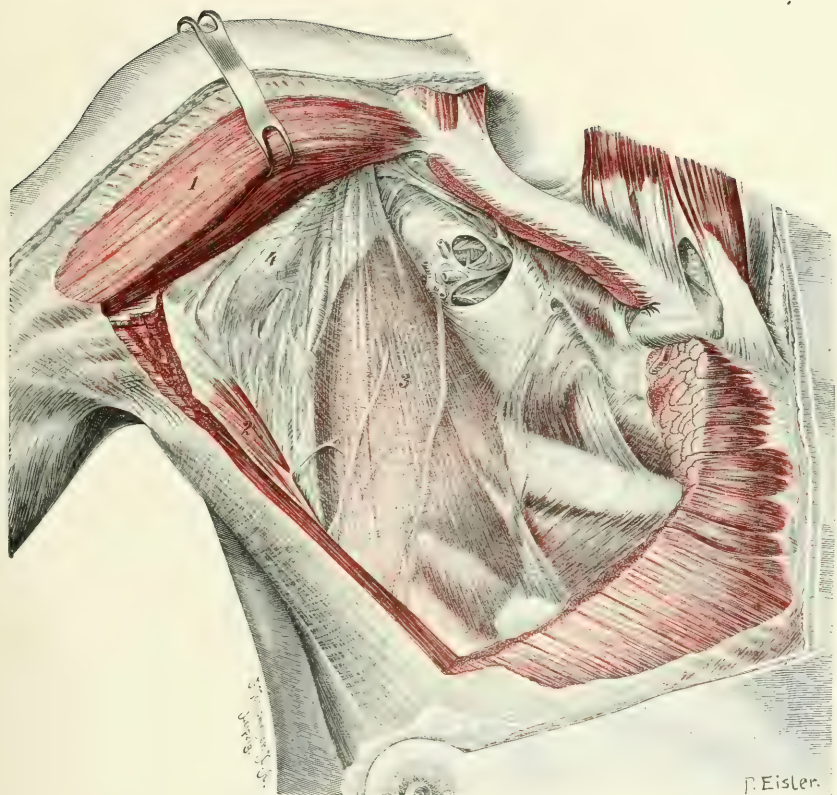


FIG. 43.—DEEP FASCIA OF THE CHEST. The pectoralis major in great part removed to show the pectoralis minor muscle, costo-coracoid membrane, and fascial sheets. (Eisler.)

1, deltoid ; 2, pectoralis major, abdominal portion ; 3, pectoralis minor ; 4, coraco-brachialis.

Along the upper border of the pectoralis minor the membrane is merged with the fascia on both superficial and deep aspects of that muscle (fig. 43). Beyond the pectoralis minor the two fascial lamellæ unite to form a single sheet which sweeps over to the coraco-brachialis muscle and, becoming considerably denser, occupies the triangular space bounded by that muscle and the border of the pectoralis minor (fig. 43). At the apex of the triangle the sheet is attached to the coracoid process; distally it is merged with the deep fibres of the axillary fascia. Where the fascia passes over on to the coraco-brachialis the fibrous bundles are mainly longitudinal. They spring from the coracoid process above and merge below with the proximal border of the tendon of the pectoralis major, or become continuous with the fascial expansion which commonly sweeps from the tendon over the coraco-brachialis. The *axillary fascia* stretches across the axillary space and forms the floor of the arm-pit, or hollow between the axillary folds. It is continuous with the fasciæ covering the pectoralis major, the latissimus dorsi, and the serratus magnus on the chest wall, as well as the fascia on the medial aspect of the upper arm. In the centre of the space the fascia is continuous with the subcutaneous fascia, and does not have the form of a continuous membrane. It is rather a trabecular plate or coarse cribriform fascia continuous with the looser trabecular tissue of the axillary space and pierced by lymphatics and the branches of the intercosto-brachial nerve. On each side of this central area, however, the fascia becomes strong and membranous, due no doubt to the stresses occasioned by the movements of the arm. If these membranous portions be isolated we have the appearance of two arched fascial bands extending between the axillary folds, one on the arm side, one on the chest. The fascia on the serratus magnus below the axilla is strong and membranous, and is continued into the median arched band. Above the level of this band the fascia on the serratus magnus is loose and scanty. In similar fashion the fascia on the medial surface of the arm, when it reaches the level of the axilla, passes into the lateral arched band, but is continued upwards beyond this as a thin membrane over the neuro-vascular bundle. The medial and lateral arched bands of the axillary fascia both merge dorsally into the fascia of the latissimus dorsi; ventrally they are in superficial continuity with the fascia of the pectoralis major beneath its lateral free border, but on a deeper plane merge with the fascial layer, already described, stretching across under the pectoralis major between the pectoralis minor and coraco-brachialis. The fascia often shows tendinous strands crossing the axilla from the posterior fold. They are believed to represent the tendinous remnants of that portion of the *panniculus carnosus* which occupies this position in lower mammals, and is sometimes present even in man in the form of the so-called axillary arches.

Muscles.—Under this group of muscles come the pectoralis major, pectoralis minor, subclavius and serratus magnus (anterior).

The two pectoral muscles, as well as a number of occasional muscles in this region, arise in the human embryo from a common premuscle mass on the medial side of the proximal part of the arm bud. This is at first in continuity with the general premuscle sleeve of the developing extremity and is placed cranial to the first rib. The developing muscle mass acquires attachments to the humerus, clavicle, and coracoid process, and then becoming flattened out it extends backwards to the region of the tips of the upper ribs. It attaches itself to the upper six ribs and sternal rudiment, and with the growth of the ribs and development of the sternum is carried towards the median plane. Meantime it has split into a superficial and a deep lamella—the pectoralis major and pectoralis minor. The subclavius arises separately, and although it is in all probability

primitively a derivative of the deep lamella of the pectoral sheet, it has become independent of it. The direction of the muscle bundles in the case of all these muscles is necessarily changed during the course of development as the pectoral girdle becomes displaced backwards.

M. Pectoralis Major (fig. 44).—The greater pectoral muscle consists of two portions, *clavicular* and *sterno-costal*, which are separated at their origin by a slight interval opposite the sterno-clavicular articulation, but are united laterally at the insertion of the muscle. The clavicular portion arises from an impression occupying the medial half of the ventral surface of the clavicle by short tendinous and fleshy fibres. The sterno-costal section springs by tendinous fibres from the ventral surface of the sternum and by fleshy and tendinous slips from the upper six costal cartilages, the ventral extremity of the sixth rib, and the upper part of the aponeurosis of the external oblique muscle where it passes into the rectus sheath.

The portion of the muscle arising from the aponeurosis of the external oblique is generally more or less separated from the sterno-costal section proper by a fibrous intersection. Further, the manubrial part of the sheet sometimes shows a certain degree of separation, so that the muscles may be divided into clavicular, presternal, meso-sternal, and abdominal sections. This subdivision is important from the comparative anatomical point of view. It will be observed that the successive superficial fibres of the muscle overlap from above the deeper fibres. This is due to the fact that during development the muscle splits into radial bundles, the superficial fibres in each bundle moving further backwards than do the deeper ones.

The muscular fasciculi converge from their extensive origin to form a thick mass which is inserted by a tendon of considerable breadth into the pectoral ridge (*crista tuberculi majoris*) of the humerus. The tendon of insertion is composed of two layers which are only united for a limited extent along their lower margins, so that a space is left between them. The ventral layer is formed superficially by the clavicular portion of the muscle, which is prolonged downwards beyond the level of the sterno-costal fibres, and becomes closely united with the tendon of the deltoid muscle. The deeper part of the ventral layer is formed by the tendon of the upper portion of the sterno-costal sheet, and consists of fibres disposed at right angles to the bone. The dorsal or posterior lamella of the tendon receives the fibres from the lower ribs and aponeurosis of the external oblique. The lower fibres turn successively behind those placed cranial to them, so that this part of the muscle appears twisted on itself, and the abdominal fibres rise highest upon the tendon. The posterior layer of the tendon reaches a higher level on the humerus than the anterior layer, and from its proximal border an expansion of variable strength is given off. It covers the long head of the biceps muscle, and is attached to the greater tubercle of the humerus and the capsule of the shoulder-joint; it not infrequently sends some fibres to the coracoid process. Further, its deepest fibres are reflected at their attachment to the bone to line the bicipital (intertubercular) groove and to meet the tendon of the latissimus dorsi. From the distal border of the tendon an expansion is given off which merges with the fascia of the arm. The arrangement by which the more superficial fibres arising nearer the shoulder-joint are inserted furthest from the joint, while the deep fibres springing further from the shoulder are inserted nearest to it, secures a concentration of the force of the muscle, acting as an adductor of the raised arm, as close as possible to the joint.

Relations.—The folded inferior border of the pectoralis major forms the anterior margin of the axilla. The superior border is nearly parallel to that of the deltoid muscle, the two muscles being separated only by a slight interval which becomes wider towards the clavicle, and in which

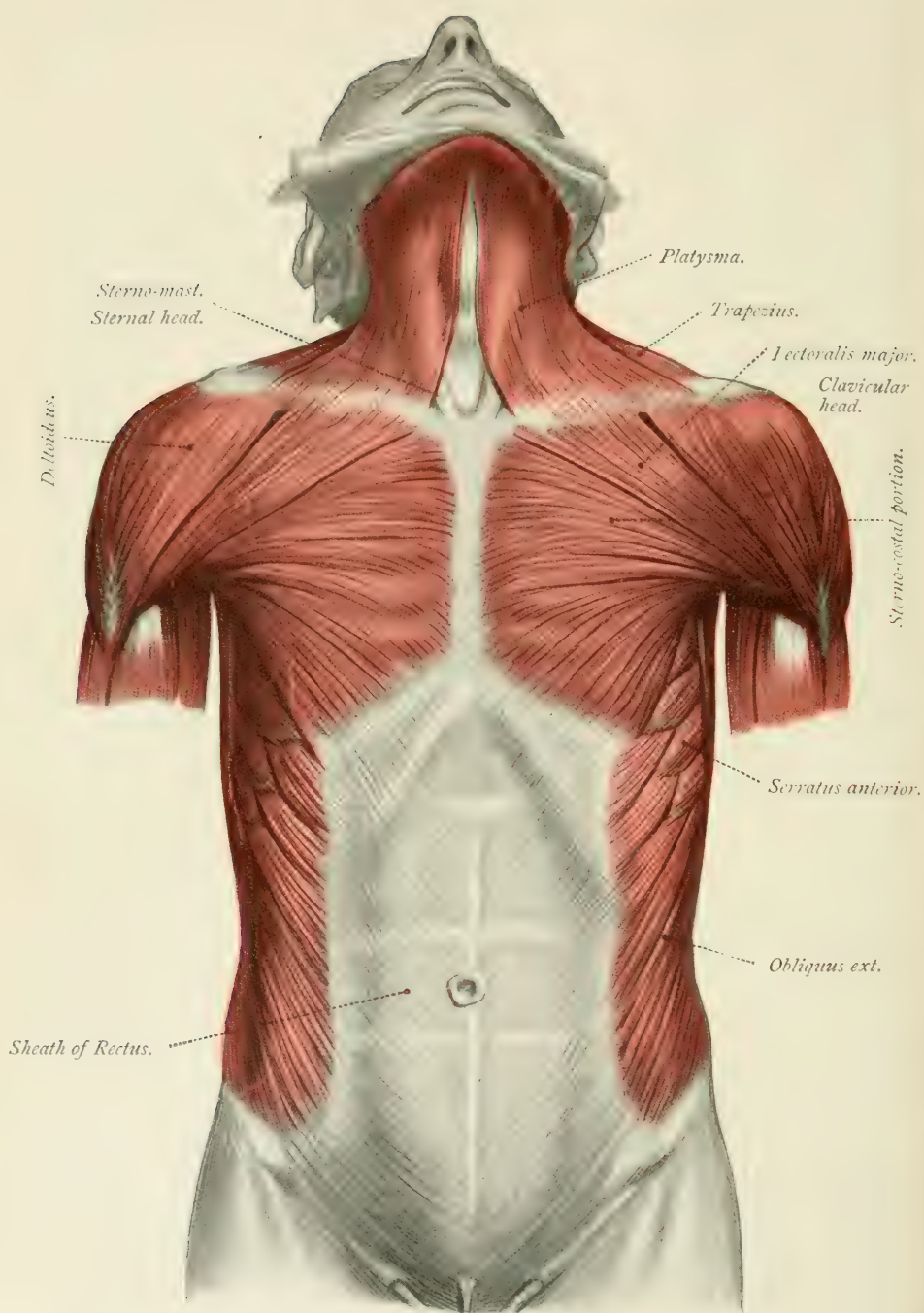


FIG. 44.—VENTRAL MUSCLES OF THE TRUNK, SUPERFICIAL LAYER.

run the cephalic vein and the humeral branch of the thoraco-acromial artery. The anterior surface is subcutaneous in the greater part of its extent, being covered only by some of the fibres of the platysma myoides and by the mamma. The posterior surface rests chiefly on the pectoralis minor, and with that muscle forms the anterior wall of the axilla. There is sometimes a bursa between the tendon and the long head of the biceps muscle.

M. Pectoralis Minor (fig. 45).—The lesser pectoral muscle arises from three ribs near their cartilages, usually the third, fourth, and fifth. The attachment is effected by tendinous slips which spring from the cranial borders of the ribs and are blended with the anterior intercostal aponeuroses, and by fleshy slips which arise from the outer surfaces of the ribs. The fibres converge to a narrow flattened tendon, which is inserted into the medial border of the coracoid process along its anterior (ventral) half and into the upper surface of the process. The tendon is in contact with the conjoined origin of the coraco-brachialis and biceps muscles, to which it is frequently bound by a fibrous expansion which may represent a remnant of the occasional more extended insertion of the muscle. A small bursa is sometimes found between the tendon and the surface of the coracoid process below the line of insertion.

Relations.—This muscle is covered by the pectoralis major, and forms a part of the anterior wall of the axilla. It crosses the axillary vessels and brachial plexus of nerves. When the arm is much raised, a portion of the muscle may be seen projecting beyond the lower margin of the pectoralis major.

Nerves of Supply to Pectoral Muscles.—The pectoral muscles receive their nerve supply from the fifth cervical to the first thoracic nerves through the anterior thoracic branches of the medial and lateral cords of the brachial plexus. The nerves reach the greater pectoral partly over, partly through, and partly behind the lesser pectoral muscle. The branches to the clavicular head are unconnected with those to the sterno-costal portion. In the latter the branches are connected by loops both before and after they enter the muscle. The small branches divide into two twigs, one medial the other lateral, so that two main lines of nerve entrance are produced, supplying a medial and a lateral zone of the sheet of muscle. The clavicular head of the pectoralis major is supplied mainly by the sixth, partly by the fifth and seventh cervical nerves, the sterno-costal portion in its upper part by the seventh, partly by the sixth, in its lower part by the eighth cervical and first thoracic nerves. The innervation is thus segmental in character, but there is a certain amount of overlapping of the regions supplied by the individual nerves. The pectoralis minor is supplied by the medial anterior thoracic nerve which conveys fibres from the seventh and eighth cervical nerves. The branches are joined together by loops before giving off their terminal filaments.

M. Subclavius (fig. 45).—The subclavius muscle arises from the first costal arch at the junction of the rib and cartilage close in front of the costo-clavicular ligament, by a short thick tendon which is prolonged for some distance along the caudal border of the muscle. The muscular fibres springing from this tendon extend laterally and upwards to form a diminutive belly which is inserted into the groove on the under aspect of the clavicle, and reaches as far as the recess between the conoid and trapezoid bands of the coraco-clavicular ligament.

Relations.—The subclavius is encased by the costo-coracoid membrane, and is placed immediately over the great vessels and nerves entering the limb.

Nerve of Supply.—The nerve to the subclavius muscle is a slender branch from the trunk formed by the union of the fifth and sixth cervical nerves. The nerve fibres come mainly from the fifth nerve, but sometimes also from the sixth or fourth.

Varieties and Morphology of the Pectoral Group of Muscles.—This group of muscles shows a special degree of variability, not only in the extent and character of the attachments of the muscles, but in the presence of a great variety of separate aberrant slips which are occasionally present. It will be recollected that the pectoral group of muscles arises from a common rudiment at the base of the limb bud. This spreads backwards and ventrally over the trunk, divides into bundles, and splits into a superficial and a deep layer. With the spreading pectoral sheet are associated, however, elements of the same origin but of another description. In lower mammals a great sheet

of muscle arises from the deep part of the primitive pectoral sheet, and spreads over the trunk far beyond the pectoral fibres. This deeper system of fibres becomes attached to the skin and gives rise to the great skin muscle or *panniculus carnosus*. Now at some stage in phylogeny man's precursor possessed such a muscle, but it has undergone retrogression in the higher primates, probably because the movements of the arm are so free that the hand can be applied to any portion of the surface of the body. The panniculus is now represented only by certain vestigial remnants in the form of muscular slips associated with the pectoral group, and supplied by the anterior thoracic nerve. Remnants of the panniculus are to be sought for on the side wall of the chest where the *pars abdominalis* of the *pectoralis major* and the *pectoralis minor* come into close relation with one another. Thus the *pars abdominalis*, when it has extra slips from the abdominal aponeurosis, when it spreads forwards on the rectus sheath, or is attached to the fascia over the serratus magnus, represents a conjunction of pectoral and panniculus elements. In the latter category are to be included such separate bundles as receive the name of *pectoralis quartus*. These are not uncommon, and occur in various forms and degrees of development. They ascend in all cases below the *pectoralis major* to be inserted in various ways, sometimes falling short on the axillary fascia, or reaching some point on the line of the attachment of the primitive panniculus, e.g. the pectoral ridge of the humerus behind the upper part of the pectoral tendon, the fascia on the biceps and coraco-brachialis, the fascial membrane between the coraco-brachialis and *pectoralis minor*, or the coracoid process. Such slips may be considered as ventral expansions of the panniculus; other bundles attached to the fascia of the serratus magnus may be looked upon as expansions of the muscle on the lateral wall of the trunk; while others again, sweeping from the border of the latissimus to the fascia of the arm or pectoral insertion, may be taken to represent a more dorsal stream. There is almost endless variety in the detailed characters of these slips as recorded in the extensive literature. In many cases marginal bundles of the latissimus, known to be such by being supplied by the long subscapular nerve, are bound up with tendinous remnants of the panniculus and so find secondary attachments to fascia, humerus, or coracoid process. The common variety of axillary arch is a fleshy slip of varying dimensions, often interrupted by a tendinous intersection, which extends from the latissimus dorsi in the axillary fascia to the *pectoralis major*. It is supplied by fibres derived from the eighth cervical and first thoracic nerves which reach the muscle in a special nerve frequently united with the medial anterior thoracic, or by another route in the nerve of Wrisberg (intercosto-brachial) (J. T. Wilson).

On the surface of the *pectoralis major* some superficial fibres which arise from the fascia over the clavicular head and are inserted into the fascia of the deltoid muscle are sometimes met with (*M. infraclavicularis*). Detached bundles are seen in other regions. The name **Sternalis** is given to a fleshy band of longitudinal fibres, often bilateral, of varying length and breadth placed close to, and generally parallel with, the sternum. It springs below, when typical, from the sheath of the rectus or the costal cartilages (third to seventh), and ends above on the fascia, or may be continued into the sternal head of the sterno-mastoid. It is supplied by the lateral anterior thoracic nerve, but some hold that its supply comes from the intercostal nerves. Divergent views prevail as to its nature. The most plausible and satisfying view is that it represents a portion of the panniculus.

The pectoral sheet divides itself into a superficial layer (ecto-pectoral) and a deep layer (ento-pectoral). The outer lamella is divided into clavicular, presternal, sternal, and abdominal portions, which may be more or less separate. The clavicular head may extend on the bone as far as the deltoid, or its origin may be confined to its sternal end. It is occasionally divided into two parts, and sometimes it is practically isolated from the rest of the muscle by a separation of the anterior lamella of the tendon of insertion.

The deep layer of the muscle is represented normally by the *pectoralis minor* and by certain muscles which only occasionally appear. The *pectoralis minor* sometimes has its insertion extended beyond the coracoid process, as in some lower mammals. The tendon in such cases is prolonged over the process, from which it is separated by a bursa, through the coraco-acromial ligament to the capsule of the shoulder-joint and greater tubercle of the humerus.

The presternal part of the deep layer is normally absent, but it may be represented in rare cases by aberrant slips. These are the *sterno-clavicularis anterior* arising from the border of the presternum and inserted into the antero-inferior border of the clavicle as far as, or even beyond, the middle of the bone; the *pectoralis minimus* arising from the first rib cartilage and crossing the costo-coracoid membrane to be inserted into the coracoid process; the *tensor semivagine articulationis humero-scapularis* springing from the first, first and second, second and third, or third and fourth rib cartilages and from the border of the sternum, to be inserted by an aponeurosis into the capsule of the joint, or rather the wall of the subacromial bursa. Another slip which has been named *sterno-humeralis* has been observed passing from the first rib cartilage and border of the sternum to the fascia of the arm. The *subclavius*, as already mentioned, is probably to be

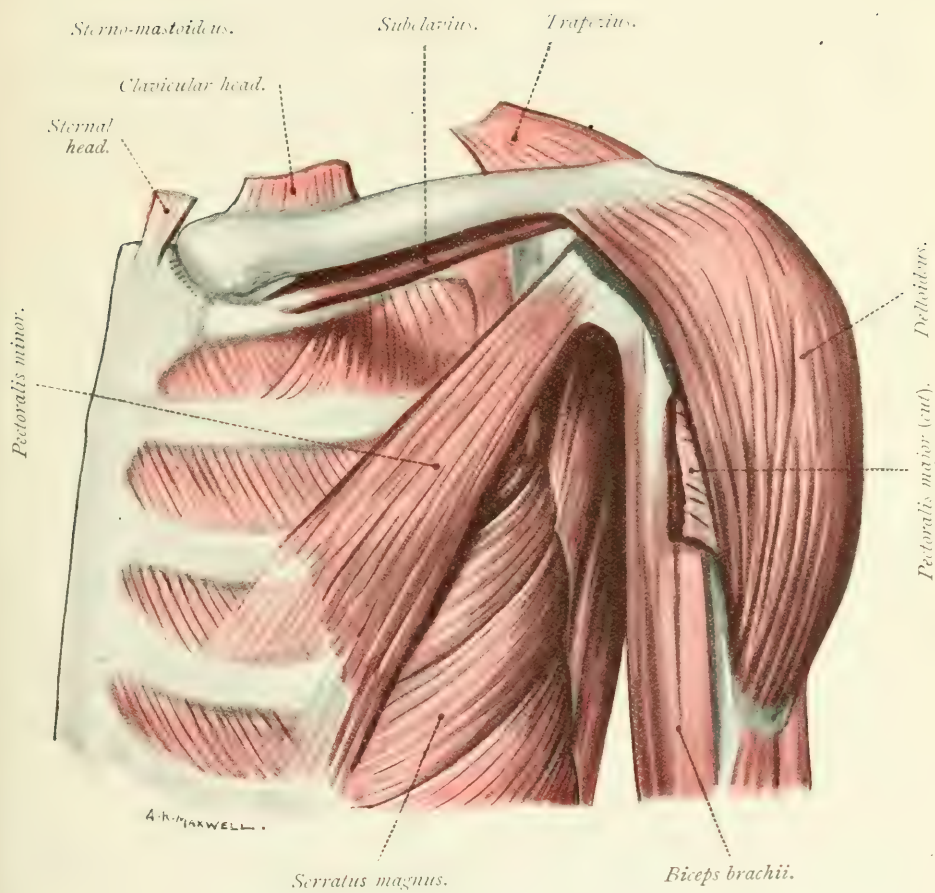


FIG. 45.—VIEW OF DISSECTION TO EXPOSE PECTORALIS MINOR AND SUBCLAVIUS MUSCLES.

regarded as a derivative of the deep lamella of the pectoral sheet. Its insertion may spread from the clavicle to the coraco-clavicular ligament, the coracoid process, the transverse ligament of the scapula, or superior border of that bone. Another muscle separate from the subclavius, placed behind it, and to be regarded as the deepest derivative of the pectoral sheet, is the *sterno* or *chondroscapularis* or *subclavius posticus*. It arises either from the first rib cartilage separate from the subclavius, or the edge of the presternum, and passes behind the clavicle and normal subclavius, to be attached to the upper border of the scapula by a fine aponeurosis or to the fascia over the supraspinatus.

Another rare variety may be mentioned, viz. the *M. scapulo-clavicularis*, a small muscle passing from the root of the coracoid and transverse scapular ligament to the back of the clavicle. The *pectoralis intermedius* is a fleshy slip, seen in rare instances arising from the third and fourth ribs between the ecto-pectoral and ento-pectoral, and inserted into the coracoid process. All these muscles in view of their innervation belong to the sphere of the fifth cervical to the first thoracic myotomes. Sometimes the insertion of the pectoralis major muscle on the fascia of the arm extends lower than usual, and a muscular slip called *chondro-epitrochlearis* has been described as arising from one or other of the ribs and descending to be attached to the median intermuscular septum or median epicondyle. It is analogous to extensions of the pectoralis major which occur normally in certain lower mammals.

M. Serratus Magnus (Anterior) (fig. 46).—This muscle, as already noted, is derived from a rudiment common to it and the levator scapulæ and rhomboid muscles. It is placed on the upper and lateral part of the thorax, between the ribs and the scapula. It arises ventrally from the first eight or nine ribs by as many fleshy slips or digitations, each digitation being attached to the outer surface of the corresponding rib with the exception of the first, which is attached to two ribs. Dorsally, the muscle, considerably narrowed, is inserted into a line along the ventral aspect of the vertebral border of the scapula, and at the medial and inferior angles of the bone into the surfaces which are excluded from the fossa of the subscapular muscle. The fibres are arranged in three sets, thus: (a) those of the first digitation, springing from the first and second ribs and an intervening aponeurotic arch, form a thick bundle which terminates on the flat area in front of the medial angle of the scapula; (b) those of the second and third digitations, from the second and third ribs, but especially from the first of these, spread out into a triangular layer, the thinnest part of the muscle, and are attached along the line on the ventral aspect of the vertebral border of the scapula, extending from the place of insertion of the preceding part nearly to the inferior angle of the bone; (c) the remaining five or six digitations converge in the form of a fan, and end in a thick mass which is attached to the flat surface on the ventral aspect of the inferior angle of the scapula.

Relations.—By its deep surface the serratus magnus rests on the upper ribs, the intercostal muscles, and part of the serratus posterior superior. Its lateral surface is in contact dorsally with the subscapular and latissimus dorsi muscles, and forms ventrally the medial wall of the axillary space, being subcutaneous in the lower part of its extent.

Nerve of Supply.—The serratus magnus is supplied by the long thoracic nerve which collects fibres from the fifth to the seventh, sometimes, according to some authorities, also from the eighth, cervical nerves. The filaments from the fifth cervical nerve supply the first digitation; the sixth and seventh nerves supply the chief mass of the muscle. If fibres come from the eighth nerve they go only to the lowest slips. According to von Schumacker, the fibres from the sixth nerve are distributed over the whole sheet. A series of branches, five or more in number, are given off from the nerve as it descends, and enter the muscle along a vertical line a little behind the mid-axillary line.

Varieties and Morphology.—In view of the innervation of the muscle from the cervical nerves, it must, like all the muscles passing from the trunk to the upper extremity, be regarded as a derivative of cervical myotomes. In this case the fifth to the seventh, sometimes also the eighth, cervical myotomes are involved. The muscle rudiment becomes attached in the course of development to the ribs before it is fixed to the scapula, and at a stage when they are far separated from the median plane. The slips spread forwards on the ribs, and later on, as the ribs grow round the body wall, the origin is carried bodily forwards. The ventro-medial surface into which

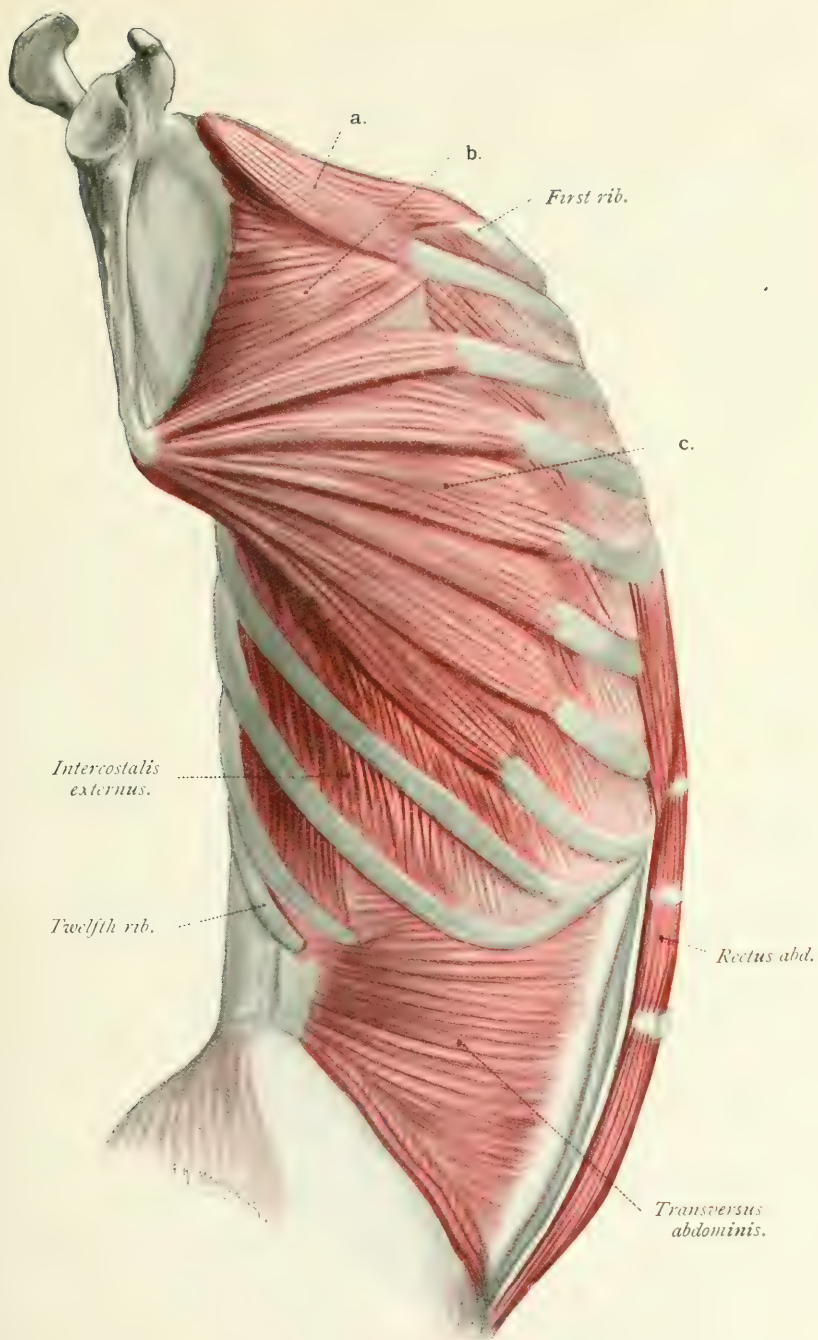


FIG. 46.—VIEW OF DISSECTION TO SHOW SERRATUS MAGNUS AND TRANSVERSUS ABDOMINIS.

- a.* Upper part arising from 1st and 2nd ribs. *b.* Middle part arising from 2nd and 3rd ribs.
c. Lower part arising from 4th to 8th ribs.

at first the nerves pass, thus becomes the lateral surface of the definitive sheet. This supplies the explanation, as Bolk pointed out, for the fact that the nerve enters on the superficial surface of the muscle. Further changes in the position of the muscle are involved in the backward and dorsal displacement of the scapula in development, and account for the fashion in which the muscle surrounds the chest wall.

The muscle receives not infrequently a slip from the tenth rib. On the other hand, the highest digitation often has no attachment to the first rib, or the lower slips may be absent and the muscle does not descend lower than the seventh rib. The sheet has been observed divided into three parts. Sometimes the middle part is defective, the gap being filled by fibrous tissue. In rare cases the muscle may be continuous with the levator scapulae, with which in many lower mammals it forms a single sheet. Sometimes muscle slips may be seen passing from the eighth or ninth and tenth ribs to be attached to the inferior angle of the scapula. These are not parts of the serratus; as they are supplied by the intercostal nerves they are to be relegated to trunk myotomes. Certain slips passing from the first and second ribs to the vertebral border of the scapula and supplied by the dorsal scapular nerve must be looked upon as belonging to the rhomboid sheet and therefore as varieties of those muscles.

Actions of the Shoulder Girdle Muscles.—The movements of the humerus at the shoulder-joint are so usually combined with movements of the scapula and clavicle that it is more convenient to describe the independent movements of the girdle bones first, and afterwards to discuss the movements of the arm.

The active movements of the pectoral girdle are primarily displacements of the scapula, and to them the clavicle ensures a precision which would otherwise be impossible, and even in some movements exercises a regulating function (see Vol. IV., Part I., p. 237). The movements of the scapula, in themselves, are concerned in the raising and lowering of the shoulder; in which motions the movements of the scapula are not wholly parallel to itself, but include, especially towards the terminations of the movements, rotations in its own plane. In raising the shoulder the acromion will be found to ascend higher than the medial angle and the inferior angle to move laterally and forwards, that is, to move away from the vertebral column. Further, the scapula may be brought forwards on the chest wall when the shoulder is raised, and in depression it may be moved backwards; but these lateral movements are normally secondary, and if not so are always constrained, even though the excursion of the scapula may be as much as 8 cm. (Fick). In raising the shoulder to its full extent, then, the scapula undergoes three displacements: a movement upwards parallel to itself, a lateral rotation in its own plane, and a movement forwards on the chest wall. The reverse movements take place when the shoulder is depressed.

The muscles which act on the shoulder girdle may therefore be divided into two groups, the elevators and the depressors of the shoulder. It should be noted, of course, that the muscles which raise the shoulder will prevent it from sinking, and that this will be their function when the shoulder is used as a pushing or weight-bearing mechanism. In the movements of the scapula each muscle tends to produce a compound displacement, so that in order to effect simple linear displacements of the bone various combinations of muscles are necessary.

TABLE III.—MUSCLES WHICH ACT ON THE SHOULDER GIRDLE

	Elevators.			Depressors (Weight of Arm).		
	Pure Elevation.	Rotation Outwards.	Forward Lateral Movement.	Pure Depression.	Rotation Inwards.	Backward Lateral Movement.
Trapezius	+ (Upper part)	+ (Middle and lower parts)	...	...	...	+ (Lower part)
Levator scap.	+	...	+ (Major)	...	+	...
Serratus ant.	...	+	+	...	...	...
Rhomboides	...	...	...	...	+	+
Latiss. dorsi	...	...	...	+	...	+ (Indirectly through arm)
Pectoralis maj.	...	...	+ (Indirectly through arm)	+ (Lower part)	...	...
Pectoralis min.	...	...	...	+	+	...
Subclavius	...	...	...	+ (Of clavicle)	...	...

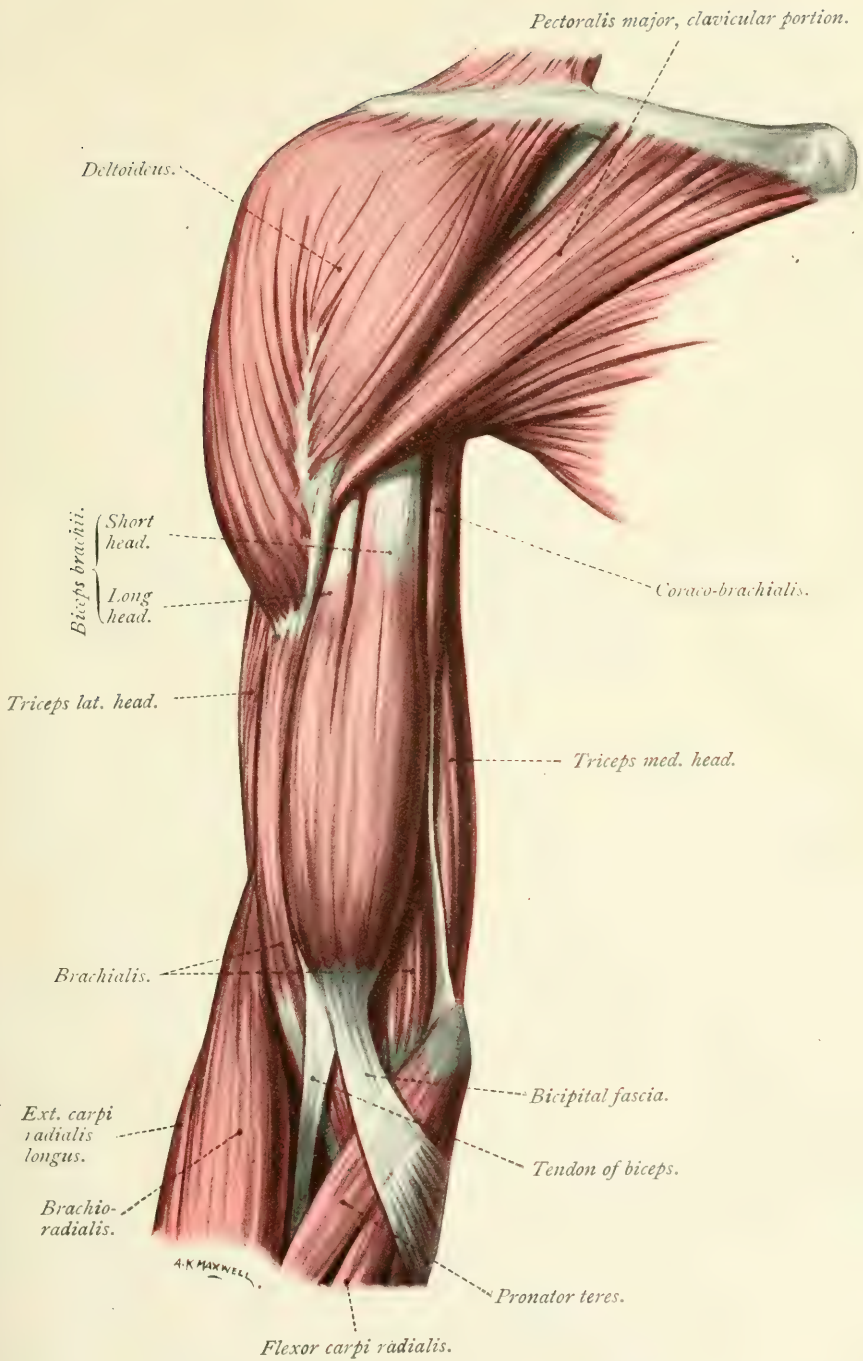


FIG. 47.—MUSCLES, FRONT OF UPPER ARM, FLEXOR ASPECT.

The *trapezius* is the chief elevator. The upper part, inserted on the clavicle, is active practically only in the slight upward movement of the girdle bones in inspiration, but the parts inserted on the acromion and the spine of the scapula acting in concert, and notwithstanding the difference of the obliquity of their fibres, are elevators of the shoulder, for they are productive of the rotation which raises the acromion and depresses the medial angle. The inferior part of the muscle, in action with the rhomboids, would tend to draw the vertebral border of the scapula towards the dorsal spines.

The *serratus magnus* is an assistant of the trapezius. It raises the scapula to a slight extent (lower part); rotates it in slight degree in the same direction as the trapezius, and is the most powerful (forward mover) of the bone, enabling the arm when raised from the shoulder to be still further outstretched. It comes into action principally in all movements of pushing, for then it prevents the backward displacement of the scapula. The *levator scapulæ*¹ draws the whole scapula upwards and slightly forwards, and acts as a pure elevator in association with the trapezius. It is, however, an antagonist to the trapezius and serratus when they raise the acromion through rotatory movement, in so far as it then moderates the relative descent of the angle to which it is attached. The *rhomboidei* are the antagonists of the serratus. They draw the scapula towards the vertebral column, and slightly upwards or directly backwards if the lower part of the trapezius acts at the same time. According to Erb, the rhomboids have no elevating action on the scapula in a trapezius paralysis.

The action of the *subclavius* muscle is confined to the acromic-clavicular joint, as it pulls the outer end of the clavicle downwards after its elevation with the scapula and assists in preventing the tendency to dislocation at the articulation.

The *pectoralis minor* is a depressor muscle antagonistic in the main to the trapezius, and effecting the inward rotation of the scapula, which is the concomitant rotation of its descent.

The pectoralis major and latissimus dorsi work indirectly on the scapula, taking part in effecting movements which accompany motions primarily induced on the humerus.

THE MUSCLES AND FASCIÆ OF THE SHOULDER

Fascia.—The muscles of the shoulder are bound together with considerable firmness by fascial sheets. Over the greater part of the deltoid the fascia is delicate, but over the dorsal part of the muscle and the infraspinatus it is dense and tendinous. A strong aponeurotic layer, bound down to the vertebral and axillary borders of the scapula, covers and encloses the infraspinatus and teres minor, where they are left uncovered by the deltoid muscle. On reaching the dorsal border of the deltoid the tendinous lamella divides into two layers, of which the deeper is continued below the muscle to the shoulder-joint, and the superficial covers its subcutaneous surface, becoming thinner as it passes forwards. The superficial layer is attached to the spine of the scapula, to the acromion process and the clavicle, and is continuous with the pectoral fascia. The supraspinatus muscle is covered and enclosed by a fascial sheet which is attached to the margins of the supraspinous fossa, and is continued laterally on the surface of the tendon of the muscle. Similarly there is a thin fascia over the subscapularis which is attached to the vertebral border of the scapula and is continued on the tendon of the muscle to the greater tubercle and bicipital groove on the humerus.

Muscles.—In this group are included the deltoid, supraspinatus, infraspinatus, the two teres muscles, and the subscapularis. The coraco-brachialis should from its action be included with them. The pectoralis major and latissimus dorsi with the deltoid muscle effect the major displacements; the other muscles closely surround the joint on all sides, effecting or controlling the movements belonging to it as a spheroidal joint.

M. Deltoideus (figs. 44, 45, 47, 48, 49).—The deltoid muscle is a triangular sheet, as its name implies, which, attached to the pectoral girdle above and extending downwards to the middle of the upper arm, covers the shoulder-joint and gives the rounded contour to the shoulder. The muscle may be divided

¹ That the levator scapulæ does not raise the "angle" of the scapula alone but the whole bone, is indicated in its B.N.A. designation.

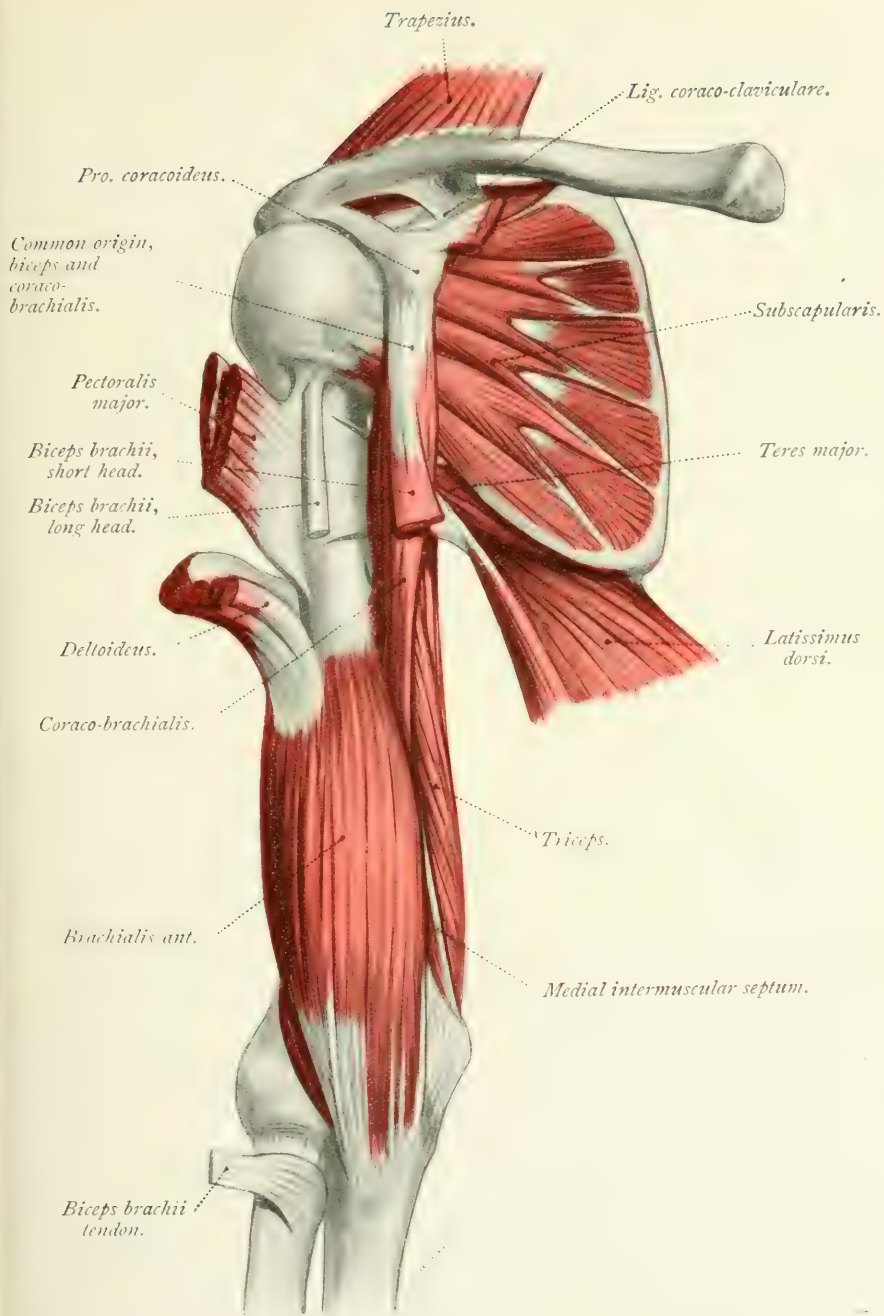


FIG. 48.—FLEXOR MUSCLES OF UPPER ARM.
The deltoid and biceps muscles have been reflected.

into three parts, viz. a ventral from the anterior border of the clavicle along its outer third, a middle from the point and lateral edge of the acromion, and a dorsal from the spine of the scapula as far back as the tubercle at its root. The fasciculi from these several parts converge as they descend, and are inserted by a strong and thick common tendon into the deltoid eminence on the lateral aspect of the humerus. The clavicular and spinous portions are composed of parallel fasciculi which end upon tendons which are concealed under the acromial head and form the marginal parts of the common tendon. The clavicular portion arises by short tendinous and fleshy fibres, but the spinous portion springs from the spine by a narrow aponeurosis which broadens towards the vertebral border and is intimately connected with the tendinous expansion over the infraspinatus muscle. The acromial portion shows a more complicated structure. While some superficial fleshy fibres arise from the bone, most of the fasciculi are attached to tendinous septa, from three to five in number, which, descending from the tendon of origin alternate, in the substance of the muscle, with others ascending from the tendon of insertion. The short oblique muscular bundles attached to the margins of the upper septa are inserted in bipennate fashion on the lower septa which intervene between the upper intersections. The muscle has thus a multipenniform structure, but its architecture is further complicated by the presence of wedge-shaped bundles of fibres which arise from the acromion in the interval between the penniform bundles, and are attached to the extremities of the lower tendinous septa, while still other bundles arising from the tips of the upper septa pass to the humerus below the level of the lower septa. The main tendon of insertion spreads from below upwards for some distance on the deep surface of the muscle.

Nerve of Supply.—The deltoid is supplied by the circumflex nerve from the posterior cord of the brachial plexus. The nerve conveys fibres from the fifth and sixth cervical nerves. The nerve divides into two main branches at a point about 7 cm. below the level of the acromion process, a posterior supplying the spinous portion and the teres minor muscle, an anterior supplying the remainder of the muscle. The anterior fasciculi of the muscle may receive their nerve supply from the anterior thoracic nerve (Froshe). The supplying twigs from the circumflex nerve enter the deep face of the muscle above its centre along a line convex downwards drawn round the neck of the humerus.

Relations.—The ventral border of the deltoid is in contact with the pectoralis major muscle distally, but is separated from it by a small interval proximally. The cephalic vein and humeral branch of the thoraco-acromial artery lie between the muscles. In contact with its deep surface is the large subacromial bursa already present at birth, which separates the shoulder-joint from the coraco-acromial arch and the deltoid muscle; occasionally present but often fused with this bursa is a second between the muscle and the greater tubercle. The muscle also covers the origin of the biceps and coraco-brachialis; the insertions of the supraspinatus, infraspinatus, and teres minor muscles, and parts of the scapular and lateral heads of the triceps muscle as well as the circumflex muscles and nerve.

Varieties.—The clavicular or even the acromial portion of the muscle have been observed to be wanting. The sheet may in rare cases be split into smaller sections, and not infrequently the three main portions are more or less separated from one another as they are in some lower mammals. A certain amount of blending of the insertion of the trapezius with the deltoid may occur, as in animals without a clavicle. Accessory slips connecting the deltoid with the infraspinatus or latissimus dorsi or teres major have been described, and not infrequently additional slips are seen arising from the vertebral border of the scapula or the infraspinatus fascia, or the axillary border of the scapula and joining the dorsal part of the muscle or expanding into the fascia. In the same category may be included slips which have been observed arising from the spine of the scapula and passing to be inserted into the humerus between the deltoid and triceps muscles or into the fascia of the arm. In connexion with the muscular slips arising from the vertebral border of the scapula or infraspinatus fascia it is of interest to note that in the gorilla and chimpanzee the spinous part of the deltoid is more extensive than in man, covers the whole of the infraspinous fossa, and has attachments to the vertebral border of the scapula and the underlying fascia. The deltoid muscle may be fixed along the greater part of its extent with the pectoralis major muscle.

It may also be connected distally with the brachialis anterior and brachio-radialis muscles. The connexion with the latter may be partly by fleshy, partly by tendinous fibres. In one case described by Macalister the acromial portion fused completely with the brachio-radialis, so that the muscle was prolonged on the radial border of the forearm as far as the insertion of that muscle. Occasionally some fibres arising from the spine extend superficially over the surface of the muscle and end in the skin of the arm.

M. Supraspinatus.—The supraspinatus muscle arises from the supraspinous fossa of the scapula to within a short distance of the neck of the bone, and from the tendinous fascia which covers and encloses it. The fasciculi converge beneath the acromion process on to a flattened tendon which adheres closely to the capsule of the shoulder-joint, and is inserted into the upper of the three facets on the greater tubercle of the humerus.

M. Infraspinatus (fig. 49).—The infraspinatus muscle is of a triangular form and occupies the greater part of the infraspinous fossa. It arises from the fascia covering it, from the under aspect of the spine, and from the inner two-thirds of the dorsal surface of the scapula within the fossa, except from those parts at the inferior angle and along the axillary border to which the teres muscles are attached. The fibres converge to a tendon which, concealed at first within the substance of the muscle, is inserted into the middle facet of the greater tubercle of the humerus. The structure of the muscle is somewhat more complicated than the above description implies. A little dissection reveals the fact that it consists of a middle deep portion which is overlapped from above and below by marginal superficial fasciculi. The upper marginal bundle arises from the under aspect of the spine and is generally more or less separate. Its fibres are parallel and are attached to the dorsal aspect of the tendon. The lower marginal bundle of superficial fibres is better developed in some cases than in others, and lies alongside the teres minor but separated from it by a fibrous septum. Like the upper bundle, when it is well developed it overlaps the middle portion and is attached to the dorsal aspect of the tendon, which thus comes to be concealed in the substance of the muscle.

Relations.—The supraspinatus muscle is covered by the trapezius and the acromion process. The suprascapular artery and nerve pass beneath it. A bursa is sometimes found between the muscle and the coraco-humeral ligament (Whittaker).

The infraspinatus is closely bound down by the tendinous fascial sheet, which divides to enclose the deltoid muscle. It is covered by that muscle at its upper and lateral part, by the trapezius at its upper and medial part, and by the latissimus dorsi at its lower angle; in the intermediate portion it is superficial. A bursa is occasionally present at the point where it is in relation to the concave border of the spine of the scapula; and another, said to be constant, separates it from the capsule of the joint.

Nerves of Supply to Supraspinatus and Infraspinatus Muscles.—Both muscles are supplied by the suprascapular nerve which proceeds from the fifth and sixth cervical nerves. The nerve after entering the supraspinous fossa gives off a branch which supplies the supraspinatus. It divides into two twigs, one which goes to the superficial and a second which ends in the deeper fasciculi. The fibres included in these branches probably come from the fifth cervical nerve. The trunk of the nerve then passes through the scapular notch and, dividing up into several twigs, is distributed to the deep surface of the infraspinatus. The points of entrance are placed near the apex of the triangular infraspinous fossa. Some branches of the circumflex nerve, according to Froshe, enter the lower part of the muscle. The infraspinatus is supplied by fibres from the fifth and probably also the sixth cervical nerve.

Varieties.—The supraspinatus is very constant in its form and attachments. Rare variations are a division of its belly into two parts; an additional slip from the suprascapular ligament; connexion between its tendon and that of the lesser pectoral muscle; a slip passing from its tendon to that of the greater pectoral or pectoral ridge of the humerus, or attachment to a tendinous lamella below the pectoralis major.

The infraspinatus is sometimes inseparably united with the teres minor muscle. A slip connecting the muscle with the posterior border of the deltoid has also been described, but this is possibly the same variety as noticed under the deltoid muscle.

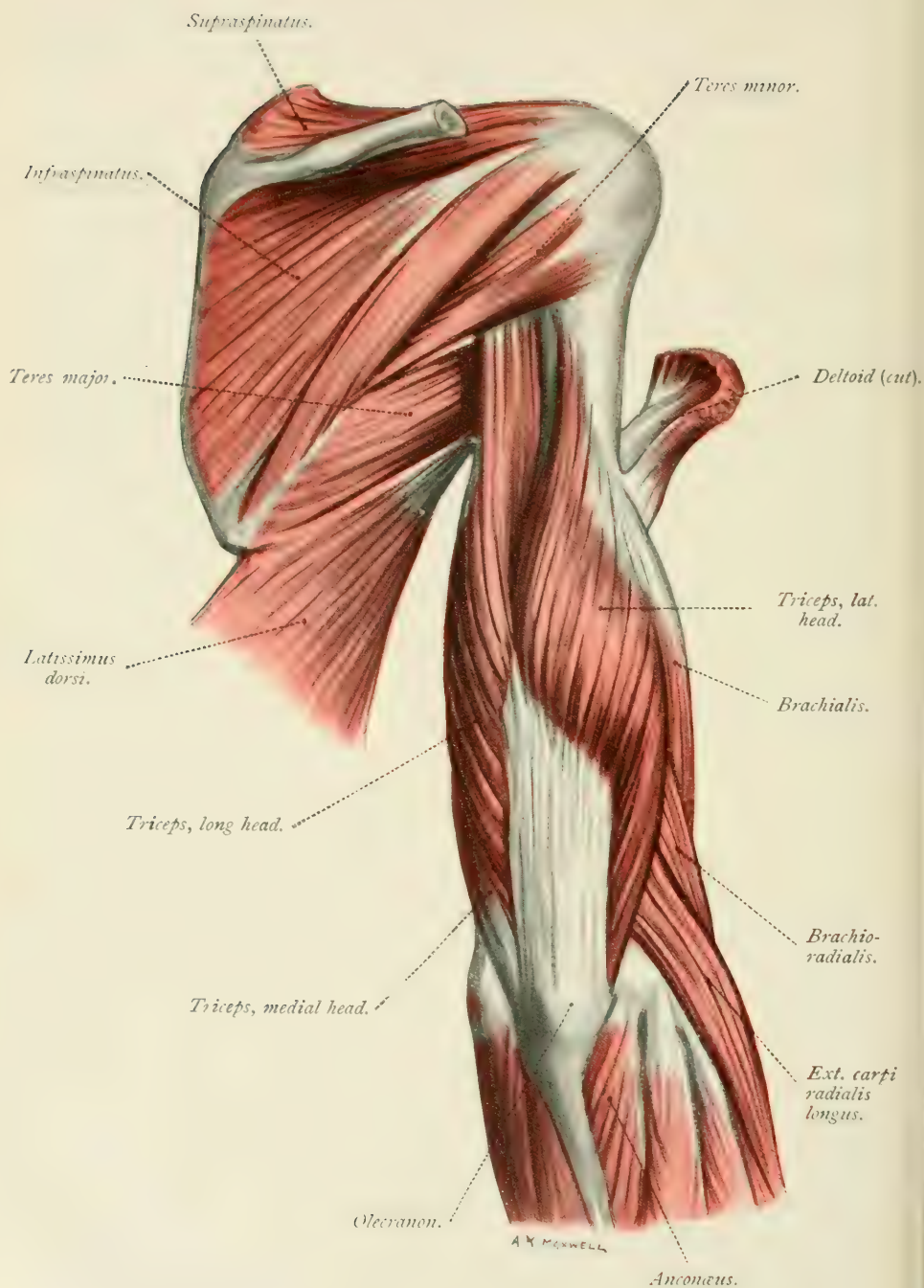


FIG. 49.—MUSCLES ON EXTENSOR ASPECT OF UPPER ARM.

M. Teres Minor (fig. 49).—The teres minor muscle is placed along the lower border of the infraspinatus, and is intimately connected with it (fig. 43). It arises from a narrow obliquely-grooved surface on the dorsum of the scapula close to the axillary border, from the strong fascia covering it, and from the fibrous septum which intervenes between it and the infraspinatus. The belly is elongated and flattened, not round as the name would imply. It is inserted by a tendon which begins on the ventral face and lower border of the muscle, into the lowest facet on the greater tubercle of the humerus, and by fleshy fibres into the bone for a short distance below the tubercle.

Nerve of Supply.—The teres minor is supplied by a branch from the circumflex nerve, which enters on its superficial aspect. This nerve has upon it a ganglioniform enlargement. The nerve fibres are derived from the fifth cervical nerve.

The muscle is partly covered by the deltoid muscle, and in front is in contact with the scapular head of the triceps and the capsule of the shoulder-joint. The scapular circumflex (dorsal scapular) artery passes between it and the bone. Its distal border is related to the proximal border of the teres major muscle, but is separated from it for part of its extent by the scapular head of the triceps muscle. A bursa is sometimes found between the tendon and the bone.

Varieties.—Failure of the muscle has been noted. The partial separation into two slips has also been recorded, one inserted into the greater tubercle, the other into the neck of the humerus (*M. teres minimus*). The origin of the muscle may be extended so that it entirely covers the infraspinatus and replaces the fascial plate covering that muscle (Waterston). Detached fleshy slips sometimes seen extending from the vertebral border of the scapula to the greater tubercle of the humerus are in all probability parts of this sheet, and the fascial lamella may represent it in tendinous form. Various slips described under the head of the deltoid muscle all come into the same category and argue for the associated origin and primary connexion of the two muscles.

M. Teres Major (fig. 49).—The teres major (fig. 43) muscle arises from the flat oval surface on the dorsum of the scapula near its inferior angle, slightly from the axillary border of the bone, and from the fibrous septum between it and the teres minor and infraspinatus muscles. It is inserted by a flat tendon, about two inches wide, into the medial border of the bicipital (intertubercular) groove of the humerus, dorsal to and in contact with the tendon of the latissimus dorsi muscle. The tendon may be adherent to that of the latissimus throughout, or only along the lower border. Near the insertion they are generally separated by a small bursa. The insertion is not always entirely tendinous. Some fleshy fibres may reach the bone over the upper half of the insertion. The fasciculi of the muscle run parallel to one another, but not parallel to the axis of the muscle. On the posterior surface they have an oblique or spiral direction, the fibres uppermost at the origin reaching the lower part of the insertion and vice versa. There is sometimes a second bursa between the tendon of the muscle and the bone, and it may be a bursa between it and the long head of the biceps.

Nerve of Supply.—The nerve supplying the muscle is the third or lowest subscapular, which comes from the posterior cord of the brachial plexus, and receives fibres from the sixth, sometimes also the fifth and seventh, cervical nerves. The nerve divides into two twigs which enter the muscle about the middle of the belly and extend in both directions, breaking up into branches which freely join one another. Its motor point may be taken as placed on the posterior axillary fold just medial to where it joins the arm raised at right angles.

Varieties.—The teres major muscle is very closely related in development to the latissimus dorsi. It is in fact a part of the same sheet. It is accordingly often fused with the fasciculus of the latissimus dorsi from the inferior angle of the scapula. A muscular slip has been observed joining the scapular head of the triceps, and also one descending upon the fascia of the upper arm on its lateral aspect. An accessory slip of origin from the vertebral border of the scapula just below the spine has been described. In rare cases the absence of the muscle has been noticed.

Relations.—Posteriorly the muscle is covered in its proximal part by the latissimus dorsi muscle, and nearer its insertion is crossed by the scapular head of the triceps muscle. The lower border is surrounded obliquely by the latissimus dorsi muscle, and the ventral surface is concealed

in the upper part of its extent by the tendon of that muscle. The upper border of the muscle forms the lower boundary of a triangular space, of which the other sides are the proximal part of the humerus and the axillary border of the scapula, covered before by the subscapularis and behind by the *teres minor* muscles. The triangular space is divided by the scapular head of the triceps muscle into two—a medial triangular, and a lateral quadriateral compartment. Through the quadrilateral space the posterior circumflex vessels and circumflex (axillary) nerve pass below the deltoid muscle. In the triangular space the circumflex scapular artery winds round the border of the scapula under the *teres minor* to reach the infraspinous fossa.

M. Subscapularis (fig. 48).—The subscapularis muscle occupies the greater part of the subscapular fossa, and the fasciculi arise in part from the bone, in part from a variable number of tendinous septa, which are attached to the bony ridges crossing the ventral surface of the scapula (fig. 48). The origin does not extend on to the neck of bone, nor on to the areas occupied by the insertion of the *serratus magnus* muscle. The muscular fasciculi end upon a broad tendon which is closely connected with the capsule of the shoulder-joint and is inserted into the lesser tubercle of the humerus. Some of the lower fibres, however, are directly inserted into the neck of the humerus for a short distance below the tubercle. The muscle is covered by the subscapular fascia which is continued laterally on to the tendon. From this some muscular fibres arise, forming a superficial layer over the lateral part of the muscle. The tendon with some dissection is seen to be divided into more or less distinct bundles. The central portion of the muscular sheet consists of two systems of fasciculi. The first comprises a series of fibres springing in pennate fashion from the sides of the tendinous septa referred to above. The fibres from each septum diverge from it, and, meeting fibres from the adjacent septa, join together to form bundles which are inserted on to, and correspond with, the bundles of the tendon. The second consists of a series of wedge-shaped masses arising from the bone between the ridges, and intervening between the pennate bundles. In each of these the fasciculi converge under the pennate bundles on to the extremities of the tendon bundles. The marginal bundles, upper and lower, consist of parallel fibres. The muscular fibres of the lower portion extend further out than those of the rest of the muscle. There is a considerable bursa which appears before birth between the tendon of the muscle and the neck of the scapula. It usually communicates freely with the shoulder-joint. There is sometimes a second independent bursal sac under the muscle below the coracoid process.

Nerves of Supply.—The subscapularis muscle is supplied by the first and third subscapular nerves from the posterior cord of the brachial plexus. The first nerve gives several filaments to the upper portion of the muscle; the third nerve gives off branches as it passes over to the *teres major* and supplies the lower marginal or axillary bundle of the muscle. A filament may also be given from the circumflex (axillary) nerve to the proximal part of this marginal bundle. In the substance of the muscle the nerve filaments run inwards towards the vertebral border, and correspond, generally speaking, to the chief or pennate bundles, while each wedge-shaped mass is supplied by two filaments, an upper and lower, which sometimes are found united by loops (Froshe and Fränkel). The segmental nerves from which the nerve fibres are derived are the fifth and sixth cervical.

Varieties.—The chief variation noted in connexion with the subscapularis is an additional muscle named the *subscapularis minor* or *secundus*, which arises from the upper part of the axillary border of the scapula and is inserted into the capsule of the joint or the humerus below the lesser tubercle. It represents those lower fibres of the muscle which are normally inserted below the tubercle, isolated from the rest. The arrangement is normally present in some lower mammals. A rarer variety is a slip arising from the tendon and passing to the axillary fascia and skin at the base of the axilla. A slip connecting the subscapularis to the pectoralis major has been observed, and sometimes the tendon is connected at its lower part with the short head of the biceps muscle.

Relations.—The tendon of the subscapularis is united with the capsule of the shoulder-joint. There is sometimes a bursa intervening between the anterior surface and the proximal ends of the

biceps and coraco-brachialis muscles. Anteriorly the muscle is in contact at its origin with the serratus magnus muscle, and is covered at its insertion by the coraco-brachialis and biceps. In the interval between the serratus magnus and coraco-brachialis and biceps muscles it forms the back wall of the axilla.

At this point, were the muscles classified according to function, the coraco-brachialis should be described as a flexor and adductor of the shoulder-joint. Both for topographical and morphological considerations, however, it is best considered with the muscles of the upper arm.

Action of the Muscles which Operate on the Shoulder-Joint

The movements at the shoulder-joint are more free and more varied than at any other joint in the body. They are almost always accompanied by movements of the scapula, or if the scapula do not move, the tendency to movement requires that the bone be fixed by the scapular muscles. Though there is, then, some accommodation of the glenoid cavity to the head of the humerus, there is always the tendency when the humerus is moved—and more especially, of course, if moved abruptly or with great force—for the head of the bone to slip from the fossa or at least to damage its orbicular ligament or the joint capsule. There is, however, a group of muscles closely investing the shoulder-joint, which are not very powerful in producing movement of the arm, but serve much more to prevent these occurrences; they might almost be named *articular muscles*, as was indeed suggested by Winslow. They comprise the supraspinatus, infraspinatus, teres minor, and subscapularis muscles. The attachments of the great muscles which effect movement at the shoulder are further removed from the joint.

The movements of the arm, though difficult to classify, are best described by starting with the humerus in the hanging position. From this position it may be carried directly forwards to the horizontal plane—this movement is usually termed flexion—and then be elevated to the vertical position; oppositely it may be depressed to the hanging position, and then be carried backwards or extended. The hanging humerus can also be carried laterally from the trunk—abduction, it is usually termed—to the horizontal line, and from there be carried to the vertical position; the return movement is adduction. In the horizontal plane the humerus may be carried forwards and backwards, movements difficult to name satisfactorily, but often referred to as horizontal adduction and abduction. In addition to these movements, the humerus may be rotated round a vertical axis so that the front of the arm is carried laterally and medially, and these are more pronounced movements than they may seem. The converse movements of the scapula on the humerus take place when the arm is fixed as in climbing.

In performing these movements there is, as would be expected at such a joint, no muscle which has a single action—with the possible exception of the short head of the biceps; but all, if they were capable of contracting singly, would produce compound displacements. From this point of view the shoulder-joint muscles may be analysed as in Table IV.

The supraspinatus muscle is usually described as an abductor of the arm from the trunk, in this assisting the deltoid. In spite of its size, however, and even its perpendicular insertion on the humerus, it cannot so act with great force owing to the closeness of its insertion to the centre of movement. Its chief use is probably to support the shoulder-joint while the arm is being raised by the deltoid, otherwise the first action of that muscle would be to push the head of the humerus upwards out of its socket. The supraspinatus forms, then, a kind of active vault, which when it contracts presses strongly downwards on the head of the bone and prevents it rising, and in this way precludes the acromial arch forming the resting place of the head of the humerus. Since a number of its fibres are inserted into the capsular ligament, it prevents that ligament being caught between the advancing head of the humerus and the edge of the glenoid cavity. According to Duchenne it has a slight rotatory action, and as shown in Table IV., Fick ascribes to it other powers. The infraspinatus is essentially a lateral rotator of the humerus, carrying its greater tuberosity backwards against the posterior border of the glenoid cavity. In this movement it has acting with it the teres minor and the posterior part of the deltoid, and as antagonist the subscapularis. The chief action, however, is probably to prevent the backward dislocation of the head of the bone in powerful forward movements of the arm. Like the supraspinatus it also acts on the joint capsule. Its further actions, as shown in Table IV., are of little account. The teres minor has very much the same action as the infraspinatus; it is a lateral rotator. It has, however, somewhat more power as a backward mover on the extending arm, and to some extent it is an adductor. The subscapularis is a medial rotator of the humerus, carrying the lesser tuberosity against the anterior margin of the glenoid cavity. In this it acts as antagonist to the infraspinatus and the teres minor

which are lateral rotators, but if both sets of muscles are contracted at once the head of the humerus will be applied firmly against the scapula. The main action is probably shown, however, when the arm is raised and carried forcibly backwards, for then it prevents the head of the humerus being displaced forwards, acting as a ligament to withstand a force which can be very great. Winslow insisted strongly that the subscapularis had no adduction action, and the researches of Fick and Weber seem to show that it rather acts as an abductor.

TABLE IV.—MUSCLES WHICH ACT ON THE SHOULDER-JOINT

	Flexion	Extension.	Abduction.	Adduction.	Horiz. (For.).	Horiz. (Back.).	Rotat (Med.).	Rotat (Lat.).
Deltoid - -	Clavic. part	Post. part	Middle part	Post. part	Ant. part	Post. part	Ant. part	Post. part
Biceps - -	+	...	? Long head	? Short head	+	...	...	...
Coraco-brachialis	+	...	...	+	+	...	...	...
Infraspinatus -	...	...	+	...	+ (F. & W.)	+ (Winslow)	...	+
Supraspinatus -	+	...	+	...	+	...	...	+ (Duchenne)
Teres minor -	+	+	...	+	...	+	...	+
Subscapularis -	+ (upper fibres)	+ (lower fibres)	+	...	+	...	+	...
Teres major -	...	+	...	+	...	+	+	...
Triceps - -	...	+	...	+	...	+	...	...
Pectoralis major -	Clavic. part	Lower part if arm is raised	...	+	+	...	+	...
Latissimus dorsi -	...	+	...	+	...	+	+	...

Note.—The large crosses in this table indicate the main actions of the muscles as ascertained in the living person; the small crosses subsidiary actions attributed to the muscles by Fick and Weber on purely mechanical grounds.

Flexion of the arm is carried out by the anterior part of the deltoid, the clavicular part of the pectoralis major,¹ the biceps, and coraco-brachialis, which can carry the humerus forwards to a level short of the horizontal plane. In this action the deltoid tends to rotate the scapula (with the acromion downwards), but this is prevented by the synergic contraction of the acromial and inferior fibres of the trapezius. The serratus magnus, it seems to have been conclusively shown by Beever, takes no part in this fixation of the scapula; for in paralysis of the trapezius, if the arm be raised, the first movement of the scapula is the rotation of its inferior angle towards the vertebral column. When flexion has advanced through about 45°, however, the serratus begins to contract and pulls the lower end of the scapula forwards, so that the normal movement of the scapula in flexion of the arm is from that angle continuously forwards. The deltoid and the other muscles then can only advance the humerus to a distance short of the horizontal plane; beyond this point the serratus magnus² and trapezius muscles rotate the scapula, and with it the humerus, and thus elevate the arm to the vertical position. The muscles which produce abduction of the humerus are the middle part of the deltoid, the supraspinatus, infraspinatus, and possibly the long head of the biceps; but here again these muscles are unable to carry the arm beyond the horizontal line, and the movement to the vertical is completed by the trapezius and the serratus as before. Cathcart, however, has described the last part of the movement as being performed by the humerus moving alone, the scapula having ceased to rotate before the vertical position is reached.

Depression of the vertical humerus to the hanging position is performed by the sternal part of the pectoralis major, the latissimus dorsi, teres major, and the long head of the triceps, the pectoralis

¹ The pectoral fibres do not contract in some people unless the arm is moved nearer the middle line than the antero-posterior plane of the joint.

² In paralysis of the serratus the trapezius then acting alone the arm cannot be moved more than a few degrees beyond the horizontal.

minor contracting synergically to fix the scapula. Duchenne includes the clavicular part of the pectoralis major in this group, as a depressor as far as the horizontal, that is, describes it as having the double action of elevation and depression to the horizontal plane. While this may be the result of electrical stimulation, Beevor denies that the muscle is voluntarily used as a depressor. The contraction of the long head of the triceps brings the biceps muscle into action to prevent the extension of the elbow which would otherwise occur. Extension of the humerus backwards from the hanging position is effected by the latissimus dorsi, teres major, and the posterior part of the deltoid. Adduction of the humerus is performed by the same muscles as depress it, with the addition of the clavicular fibres of the pectoralis major, the teres minor, coraco-brachialis, and the posterior fibres of the deltoid (Winslow). There has been considerable discussion, however, about the action of the posterior part of the deltoid, and for long the opinion of Bichat, which was supported by Duchenne, held sway; that is, that the posterior part of the deltoid contracts with the other parts of the muscle to abduct the humerus, but only through an angle of 45° , for beyond this point it acts as a depressor. More recent observers consider this part of the deltoid not to contract in simple abduction, but to be an adductor (Fick, Weber, Beevor). In the movements of depression and adduction, the pull of the teres muscles tends to displace the scapula into the axilla, but it is fixed by synergic contraction of the rhomboids and the lower part of the trapezius (Erb). In both movements, also, and even when the resistance to the movement is very small, there is a contraction of the rectus and obliquus externus abdominis to fix the ribs and prevent them being raised by the pectoralis major (Winslow; see also Wood-Jones).

The muscles which effect horizontal movement and rotation medially and laterally are sufficiently detailed in Table IV.

THE MUSCLES AND FASCIÆ OF THE UPPER ARM

Fasciæ.—The superficial fascia of the upper limb has the ordinary features seen elsewhere over the body. It contains relatively little fat, and includes between its lamellæ the superficial veins and the cutaneous nerves. It is specially distinct opposite the bend of the elbow where the veins are numerous and large. The fat is sparse over the dorsum of the hand. In the palm the subcutaneous tissue forms a fine connecting medium between the skin and the strong palmar aponeurosis; it consists of a network of fibres passing between these two structures dividing the subcutaneous fat into small granular masses, and preventing the skin from shifting to any considerable extent.

The **deep fascia** of the upper arm forms a complete investment for the muscles to which it is loosely attached. Above it is continuous with the fasciæ of the shoulder and axilla already described; below it passes over the elbow to merge with the fascia of the forearm. It is thin over the biceps muscle, stronger where it covers the triceps, and particularly dense where it approaches the epicondyles of the humerus. It is composed chiefly of transverse fibres held together by others having a longitudinal or oblique direction. Over the bend of the elbow, where it passes on to the bicipital fascia (lacertus fibrosus), the striation is mainly longitudinal and the transverse fibres are very oblique. It is pierced by various vessels and nerves. The largest aperture is placed on the medial side of the arm, close below the middle, and serves for transmission of the basilic vein and medial cutaneous nerve of the forearm.

On each side in the distal half of the arm the investing layer finds attachment by two deep processes to the epicondyles, and the ridges on the shaft of the humerus leading proximally from them. These processes form fibrous partitions which divide the upper arm into two muscular compartments for the flexor and extensor muscles respectively. They attach the investing layer to the bone, and are intimately connected with the neighbouring muscles.

The **medial intermuscular septum** (figs. 48, 50), much the stronger and better defined of the two, extends along the line from the medial epicondyle to behind the insertion of the coraco-brachialis muscle. It is broad below and tapers to a point above. It is pierced near the elbow by the inferior ulnar

collateral branch of the brachial artery. The *internal brachial ligament* (Struthers) is a fibrous band connected with the medial intermuscular septum. It extends from the medial side of the humerus, below the insertion of the *teres major* muscle, to the medial epicondyle. The ulnar nerve and deep brachial artery pass backwards between this band and the septum proper. It is connected by fibres with the insertion of the coraco-brachialis. The **lateral intermuscular septum** extends proximally from the lateral epicondyle along the lateral epicondylar ridge to the under part of the insertion of the deltoid. It is well defined only from the last-named point down to the origin of the brachio-radialis muscle. It is pierced from behind forwards by the musculo-spiral (radial) nerve and deep brachial artery, and there is often a distinct fibrous arch over the aperture for these structures.

At the level of the elbow the fascia is closely united to the periosteum covering the subcutaneous parts of the bones, viz. the epicondyles of the humerus and the olecranon process of the ulna. It is strengthened in front and behind by tendinous fibres derived from the biceps and triceps muscles. There is generally a bursa in the subcutaneous fascia over the olecranon, and occasionally one over the medial epicondyle. A bursa over the lateral epicondyle is of rare occurrence.

Muscles.—The muscles are the coraco-brachialis, biceps, brachialis anterior, and triceps. The coraco-brachialis is a flexor and adductor of the shoulder, and should be grouped physiologically with the muscles acting on that joint. The remaining muscles act primarily on the elbow, and as this is a uniaxial joint, they are arranged in simple fashion as flexor and extensor masses. Each, however, shows a superficial layer extending from the scapula to the forearm over both shoulder and elbow, consequently operating on both joints, and a deep layer attached to the humerus, whose action is confined to the elbow. The coraco-brachialis, biceps, and brachialis anterior muscles develop close together, probably from a common premuscle mass, and are supplied by the same nerve, the musculo-cutaneous, derived from the fifth, sixth, and seventh cervical nerves.

M. Coraco-Brachialis (figs. 47, 48).—The coraco-brachialis muscle of elongated form arises from the tip of the coracoid process of the scapula between the lesser pectoral muscle and the short head of the biceps. It is intimately connected with the latter muscle, and is for some distance conjoined with it in a common tendon. The distal end of the muscle is inserted into the medial border of the humerus near its middle, on a linear impression of from one to two inches in length, placed between the origins of the triceps and brachialis anterior muscles. More proximally some of the fibres are, almost invariably, inserted into a fibrous band which forms an arch over the tendons of the latissimus dorsi and the *teres major* muscles, and is attached to the humerus below the lesser tubercle. The muscle is usually pierced by the musculo-cutaneous nerve, and when this is the case it is divided into two portions which are morphologically distinct.

Varieties.—The adductor sheet so powerfully developed in the thigh, and continued to the lower end of the femur in the tendon of the adductor magnus muscle, is largely suppressed in the arm. The coraco-brachialis, though in function chiefly a flexor muscle, represents the adductors of the thigh. It seems to be developed from a premuscle mass common to it, the biceps, and brachialis anterior, the nerve to which is the musculo-cutaneous.

The muscle consists typically, as long ago demonstrated by Wood, of three portions, viz.: (1) a proximal part arising from the coracoid process and inserted into the humerus close below the lesser tubercle; (2) a middle part corresponding to that usually described in human anatomy, of intermediate size, and placed between the first and third; (3) a distal part, which is the largest and most superficially placed. It may descend to the medial epicondyle or near it, and is inserted into a supracondylar process if such exists. All these parts are found in various forms and degrees of

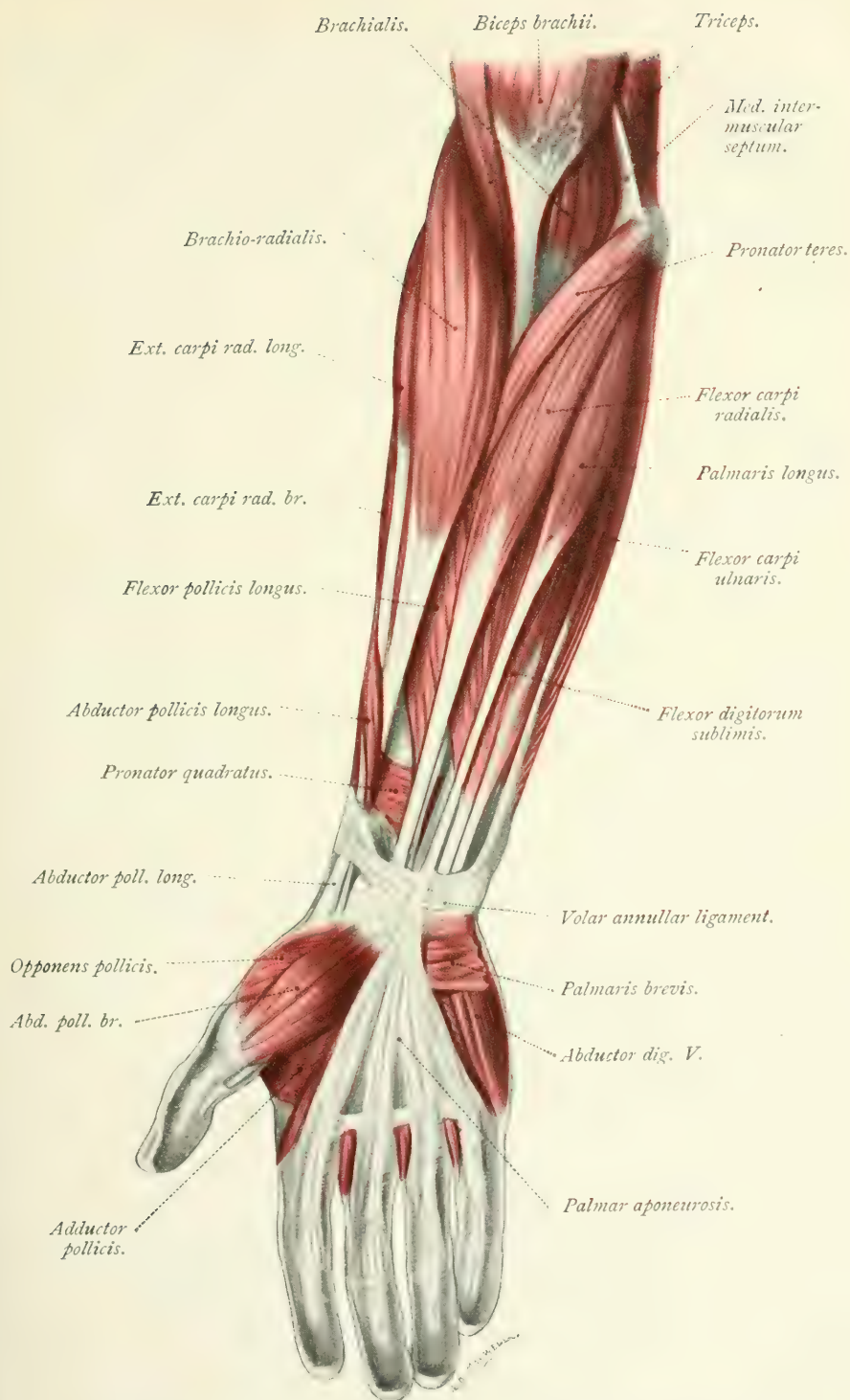


FIG. 50.—MUSCLES OF FLEXOR ASPECT OF FOREARM, SUPERFICIAL LAYER.

development in different animals. In man the middle portion is the most constant, but is generally accompanied by a part of the third, the musculo-cutaneous nerve passing between them. This distal portion is occasionally found quite separate from the other. The first part is represented by the occasional proximal extension of the insertion on to the surgical neck of the humerus or capsule of the shoulder-joint, or by an accessory head (*coraco-brachialis superior* or *brevis*). The distal portion is sometimes present in the form of the *coraco-brachialis longus* or *inferior*, attached to the humerus, the fibrous band in connexion with the medial intermuscular septum, or even the medial epicondyle. The muscle is sometimes connected with the brachialis anterior, and a fasciculus has been observed joining the medial head of the triceps muscle.

Relations.—The lateral border of the muscle is overlapped by the biceps muscle, and its medial border is in contact with the brachial artery by which it is crossed obliquely near its insertion. It lies in front of the tendons of the subscapularis, latissimus dorsi, and the teres major, and is covered in great part by the deltoid and pectoralis major muscles.

M. Biceps Brachii (figs. 47, 48).—The biceps muscle arises from the scapula by two tendinous heads. From these, muscular fibres arise which unite to form a single thick flattened belly with a somewhat convex ventral face. The common belly ends distally in a strong tendon which is attached to the tuberosity of the radius, and also gives off from its medial border a fibrous expansion to the fascia of the forearm. The *medial or short head* springs from the coracoid process. The tendon of origin which is common to it and the coraco-brachialis muscle, broadens out on the ventral face of the head, and gives rise to parallel running muscular fasciculi on its dorsal aspect and medial border. The *lateral or long head* arises from an impression above the glenoid surface of the scapula, within the capsule of the shoulder-joint, by a rounded tendon which is continuous on each side with the glenoid lip. The tendon, passing over the head of the humerus, leaves the joint by the bicipital (intertubercular) groove, within which it is invested for some distance by a sheath continuous with the synovial membrane of the joint. In the lower part of the groove the tendon expands, and is continued round its circumference over the conical apex of a muscular mass which forms the fleshy portion of the head. The two muscular heads meet generally about the middle of the arm, and becoming closely applied together, form the elongated and thick belly. This belly occupies the middle and lower parts of the arm, but a little above the bend of the elbow it suddenly becomes narrower, and is continued into the thick tendon of insertion. The tendon passing over the front of the elbow-joint, and slightly twisting upon itself as it descends, is inserted into the rough posterior portion of the tuberosity of the radius. Between the tendon and the anterior smooth part of the tuberosity there is invariably a synovial bursa, while there is often a second bursa on the medial side of the tendon between it and the bicipital hollow of the ulna. From the medial side of the tendon and distal part of the muscle a strong, flat aponeurotic band passes distally and medianwards to become blended with the deep fascia of the forearm over the muscles arising from the medial epicondyle. It is named *lacertus fibrosus*, *semilunar fascia*, or *bicipital fascia* (fig. 47).

Varieties.—The biceps is a very variable muscle. Its instability is probably due to its characters having been acquired late in the human phylum. It was originally a single-headed muscle arising from the coracoid bone, merged below with the brachialis anterior, and attached with it by a common tendon to both bones of the forearm. It then acquired a second head from the base of the coracoid, and the primary head became fused with that of the coraco-brachialis on the regression of the coracoid. The second head is the long head, and is really a coracoid not a scapular head morphologically. The muscle also became differentiated from the brachialis and probably ended, as it still does in some forms, on both bones of the forearm. The radial insertion then became dominant. It has been suggested that perhaps the fibres which pass to the semilunar fascia represent the ulnar contingent. In a few cases the tendon has been seen to give slips to the coronoid process. Further, the muscle probably had originally a humeral head. This exists in many lower mammals, and it is a normal feature in the gibbon, although not in the other *Simiidae* (*caput*

tuberculo-septalis, Gronroos). A humeral head of one kind or another appears in about 10 per cent. of arms. The different slips that appear are probably detached portions of the tuberculo-septal head. They arise along the line of origin of that muscle in the gibbon. There are three such accessory portions, and they may be present singly or in combination so that the muscle may appear to have three, four, or five heads. The commonest slip is one arising from the humerus at the insertion of the coraco-brachialis, extending between it and the brachialis muscle. It joins the short head, but most of its fibres pass into the semilunar fascia. It is sometimes isolated and ends entirely on the fascia. The two other accessory heads are rarer and take several different forms. When fully developed they arise close together from the neck of the humerus below the lesser tubercle and behind the pectoral tendon to which they are more or less united. The origin, which is by tendinous fibres, ascends to the capsule of the shoulder-joint and descends a variable distance towards the origin of the first slip described. The lateral of the two slips joins the long head, the medial the short head of the muscle. Cases have been described in which, on the other hand, the two portions of the muscle are separate throughout, as in carnivores. One or other head may be absent, and one instance has been recorded in which the whole muscle was absent. Short of actual deficiency of the long head, the tendon may be found arising from the bicipital groove, one or other of the tubercles, or the capsule of the joint or tendon of the greater pectoral muscle. On the other hand, the tendon has been seen duplicated. The long head is believed to have become included within the capsule in the course of phylogeny, and various stages of the process are to be observed in different animals. In the human fœtus of the third month the tendon is attached to the capsule by a fold of synovial membrane which disappears in the fourth month. At the distal end of the muscle various muscular or tendinous slips have been described connecting it with the lower end of the humerus, the ulna, the fascia, or neighbouring muscles. Thus occasionally a fleshy slip is given off from the medial border of the muscle to the medial intermuscular septum or the medial epicondyle passing over the brachial artery. Fasciculi have also been seen passing to the brachialis anterior, the pronator teres, the flexor carpi radialis, or on the lateral side, the brachio-radialis.

Relations.—Concealed proximally by the deltoid and pectoralis major muscles, the fleshy belly of the biceps forms in the rest of its extent the prominence of the front of the arm. It lies on the humerus above, on the brachialis anterior below. Its medial margin is in contact in its proximal half with the coraco-brachialis, in its distal half with the brachial artery. Its tendon of insertion passes backwards in the bend of the elbow, between the brachio-radialis and pronator teres muscles, and the semilunar fascia is stretched across the brachial vessels and median nerve, which lie on the medial side of the tendon. A bursa is said to exist between the tendon of the subscapularis and the common head of the biceps and coraco-brachialis muscles.

M. Brachialis Anterior (figs. 48, 50, 51).—This muscle forms the deep lamella of the flexor sheet, and covers the front of the shaft of the humerus in its lower half. It lies immediately behind the biceps, but projects beyond it both medially and laterally. It arises not only from the bone but from the intermuscular septa on either side. At its proximal extremity it embraces the insertion of the deltoid muscle by two angular fleshy processes. The medial of these is short and thin, the lateral is longer and extends upwards to occupy the larger division of the spiral groove as far as the proximal limit of the deltoid eminence. The muscular belly reaches below to the proximal attachment of the capsule of the elbow-joint, and medially it is attached to the epicondylar ridge and the intermuscular septum along its whole length. Laterally it is separated for the greater part of its extent from the lateral septum by the brachio-radialis and extensor carpi radialis longus muscles, and only arises from it for a short distance at its upper end. The muscular fasciculi are mainly vertical, but the marginal bundles, more especially the lateral, incline obliquely as they converge to a thick mass placed on the front of the elbow-joint, to the capsule of which it is closely adherent. The tendon has meantime appeared on the ventral face of the muscle. It descends vertically and then turns backward to be inserted into the tuberosity of the ulna, on the lower part of the coronoid process. In addition some of the fibres from the lateral intermuscular septum, and also the deeper fibres of the muscle, are attached directly to the coronoid process proximal to the main tendon. A portion of the muscular belly adjoining the brachio-radialis, in view of the fact that it is supplied by the musculo-spiral

nerve, which lies upon it under cover of the brachio-radialis muscle, should perhaps be differentiated as a separate morphological factor of the muscle. The great development of the biceps in man has put the brachialis in a secondary position. It extends in lower mammals to the proximal extremity of the bone, and has then a strong lateral head. In Iguana this is fused with the outer head of the triceps, and it is possible that in mammals part of the extensor sheet is included in the muscle belly. In man this outer mixed head is reduced to the small portion supplied by the musculo-spiral nerve.

Varieties.—The most frequent varieties of the muscle consist in the subdivision into two or sometimes more parts. When the muscle is thus divided the distal attachments are irregular and variable. They may be attached (1) to the coronoid process of the ulna, (2) to the radius on or below the tuberosity or to both bones, (3) to the radius and a tendinous band between it and the coronoid process, (4) to the fascia of the forearm or to the muscles of the forearm arising from the medial epicondyle. A slip from it may pass to the semilunar fascia, and a deep detached bundle has been observed attached to the capsule of the elbow-joint (*M. capsularis-subbrachialis*, Macalister). The brachialis anterior is sometimes closely connected, or even fused with the brachio-radialis muscle.

Nerve Supply to the Flexor Group of Muscles.—The nerve which supplies this group of muscles is the musculo-cutaneous. The nerve generally pierces the coraco-brachialis but does not always do so. When it does, it separates the muscle into a superficial lamella and a deep lamella between the nerve and the bone. The nerve in either case passes into the cleft between the biceps and the brachialis anterior, and here gives off branches which supply these two muscles.

The branch to the *coraco-brachialis* comes off from the lateral side of the trunk near its origin from the lateral cord of the brachial plexus, or even from the cord direct. It enters the medial surface of the muscle above the point where it is pierced 7.35 cm.¹ below the tip of the acromion process on a line drawn to the lateral epicondyle of the humerus. It is of interest in connexion with the morphology of the muscle to note that there may be two branches, one supplying the deep part, and a second, given off at the point of perforation, to the superficial part of the muscle. The nerve for the *biceps* comes off the musculo-cutaneous trunk at a variable distance from its point of exit from the coraco-brachialis muscle (12.99 cm. from acromion on the average), and divides into two branches, one for each head. Each branch subdivides at a *hilum* of some extent into a number of twigs which are distributed proximally and distally in the muscle substance, joining one another to form an intramuscular plexus. The supply to the two heads is not completely independent. The point of entry is just about the middle of the upper arm, 15.28 cm. from the acromion. The main branch to the *brachialis anterior* arises at a lower level than that to the biceps, has a longer course, and divides into several considerable branches which enter separately the ventral surface of the muscle about the junction of the middle and lower thirds of the upper arm. The hilum has a vertical extent of about 3 cm., the central point being placed at 20.27 cm. down the arm from the acromion. A smaller branch was observed arising from the lateral side of the nerve to enter the lateral border of the muscle about 24 cm. from the tip of the acromion. According to Froshe and Fränkel, the muscle receives a twig from the median nerve as it lies along the medial border of the muscle. Further, a branch generally enters its lower lateral part from the musculo-spiral. It is possible that this is an afferent nerve.

The nerve fibres to the coraco-brachialis are derived from the seventh (or sixth and seventh) cervical nerve; those for the biceps and brachialis from the fifth and sixth cervical nerves.

The **extensor group of muscles** in the arm includes the triceps and the anconæus. The latter belongs topographically to the forearm, but is in reality a distal extension of the triceps, and has been called by some, on that account, the fourth head of the triceps muscle.

M. Triceps Brachii (fig. 49).—The triceps occupies the whole posterior brachial region. The greater part of it is subcutaneous; only at the proximal part

¹ The figure given here and others utilised later are taken from the data provided in a paper by Dr E. A. Livell, *Journ. Anat.*, vol. lv., 1921. The particulars regarding the nerve supply to the muscles of the limbs are largely founded on unpublished data furnished by Mr Cappell from dissections carried out in 1918 in the Anatomy Department of the University of Glasgow. In respect of the arm the measurements relative to the bony points correspond very closely to Dr Livell's averages which are incorporated in this account.

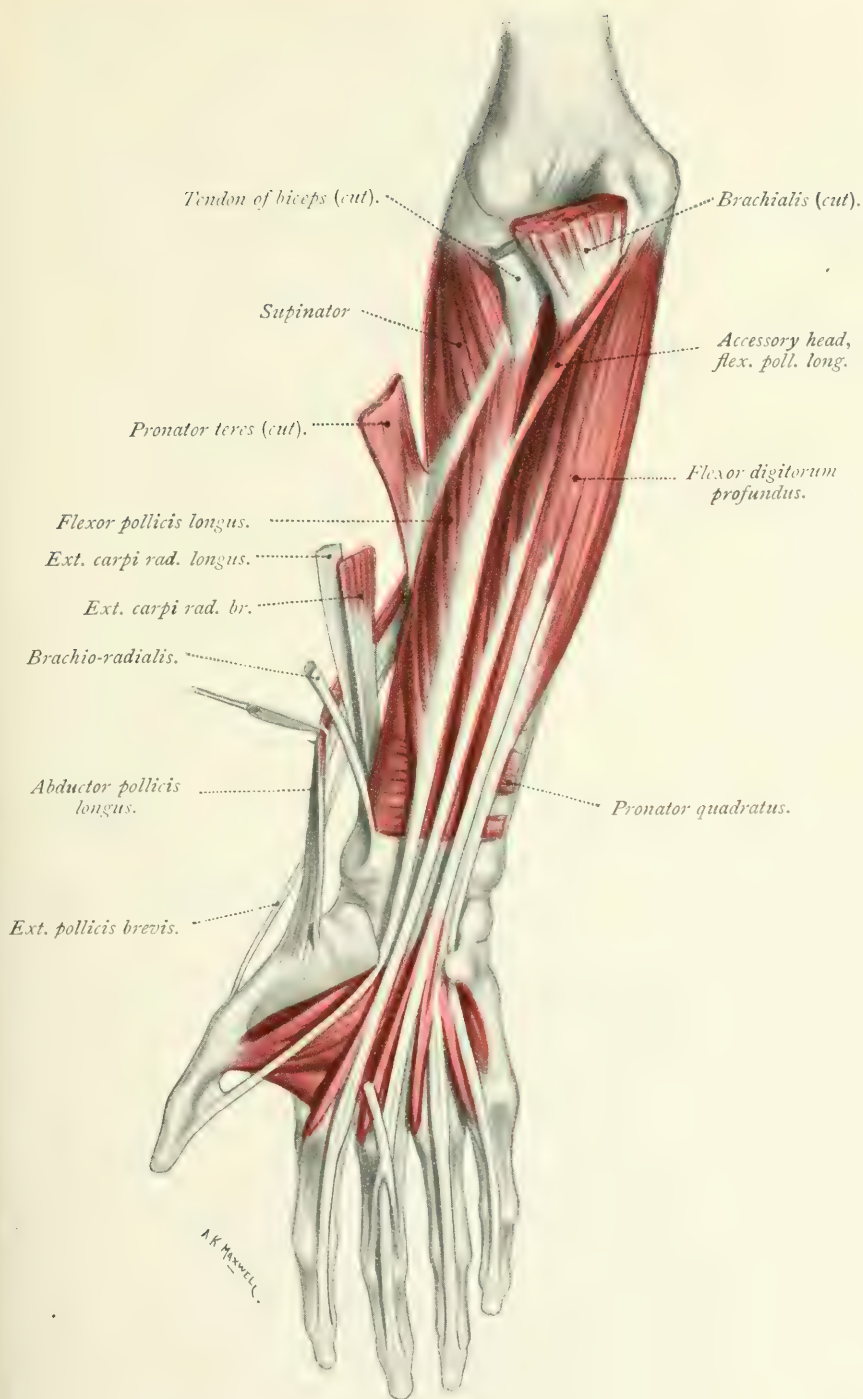


FIG. 51.—MUSCLES OF FLEXOR ASPECT OF FOREARM, DEEP LAYER.

of the arm is it overlapped by the deltoid muscle. It consists of three separate portions or heads, which are united below in a common tendon occupying the posterior surface of the mass from the middle of the arm to the elbow, where it ends by being inserted into the olecranon process of the ulna.

The *middle* or *long head* arises from the rough triangular impression on the lower part of the neck and adjacent part of the axillary border of the scapula by means of a tendon which intervenes between the two teres muscles and is closely connected with the shoulder-joint. This tendon consists of two lamella, an anterior and posterior which are united along their lateral margins, but separate medially. Between the two lamella the fleshy fibres of the head arise and can be followed nearly to the bone. The posterior lamella is prolonged over the muscular mass a short distance only, but the anterior descends a considerable way on the face of the muscle. A subsidiary attachment to the latissimus dorsi tendon, by means of a fibrous arch which passes below the tendon of the teres major, seems to be a constant feature. The head forms the middle and most superficial part of the muscle, and its fibres end along the medial margin of the common tendinous expansion. The *lateral head* takes origin by tendinous and fleshy fibres from the proximal and lateral part of the dorsal surface of the humerus, extending from the insertion of the teres minor as far as the spiral groove, and from an aponeurotic arch formed by the lateral intermuscular septum as it crosses this groove. The musculo-spiral nerve and deep brachial artery pass under this arch, as they wind round the humerus between the lateral and deep heads of the muscle. The muscular fasciculi, which are comparatively short, descend obliquely to be inserted into the proximal end and lateral border of the tendon. The *deep head*,¹ the shortest of the three, arises by fleshy fibres from the whole extent of the dorsal surface of the humerus below the spiral groove, reaching by a pointed process placed on the medial side of this groove as high as the insertion of the teres major muscle. It also arises from the medial intermuscular septum along its whole length, and from the distal part of the lateral septum. The muscular mass is thus seen to extend both medially and laterally beyond the limits of the covering tendon. Some of its distal and deep fibres are inserted directly on to the olecranon process, but the greater part of them are attached to the deep surface of the common tendon.

The tendon, which as already stated appears on the posterior face of the muscle as high as the middle of the arm, is formed by the union of tendinous lamella belonging to the long and lateral heads. That of the long head extends some distance upwards on its anterior face. The insertion of the common tendon takes place mainly into the tuberosity of the olecranon process. From its lateral aspect, however, a considerable band is prolonged distally over the anconæus (fig. 52), blending with the fascia of the forearm, in which the fibres can be followed to the dorsal border of the ulna. This expansion from the tendon is analogous to the corresponding expansion from the biceps tendon on the front of the arm. A bursa frequently intervenes between the tendon and the olecranon process and the capsule of the joint.

M. Subanconæus.—This name is given to a bundle of muscular fibres which are discovered in many cases on removing the triceps from the distal part of the humerus, and which pass from the bone to the capsule of the elbow-joint. The muscular slip is analogous to the subcrureus in the lower limb.

¹ This head is generally called the *medial head*, a name which is apt to give rise to some misconception of its nature and position. It is really a deep part of the extensor mass overlapped by a more superficial part formed by the other two heads, and is in great part covered by the tendinous expansion, in the actual formation of which it takes no part.

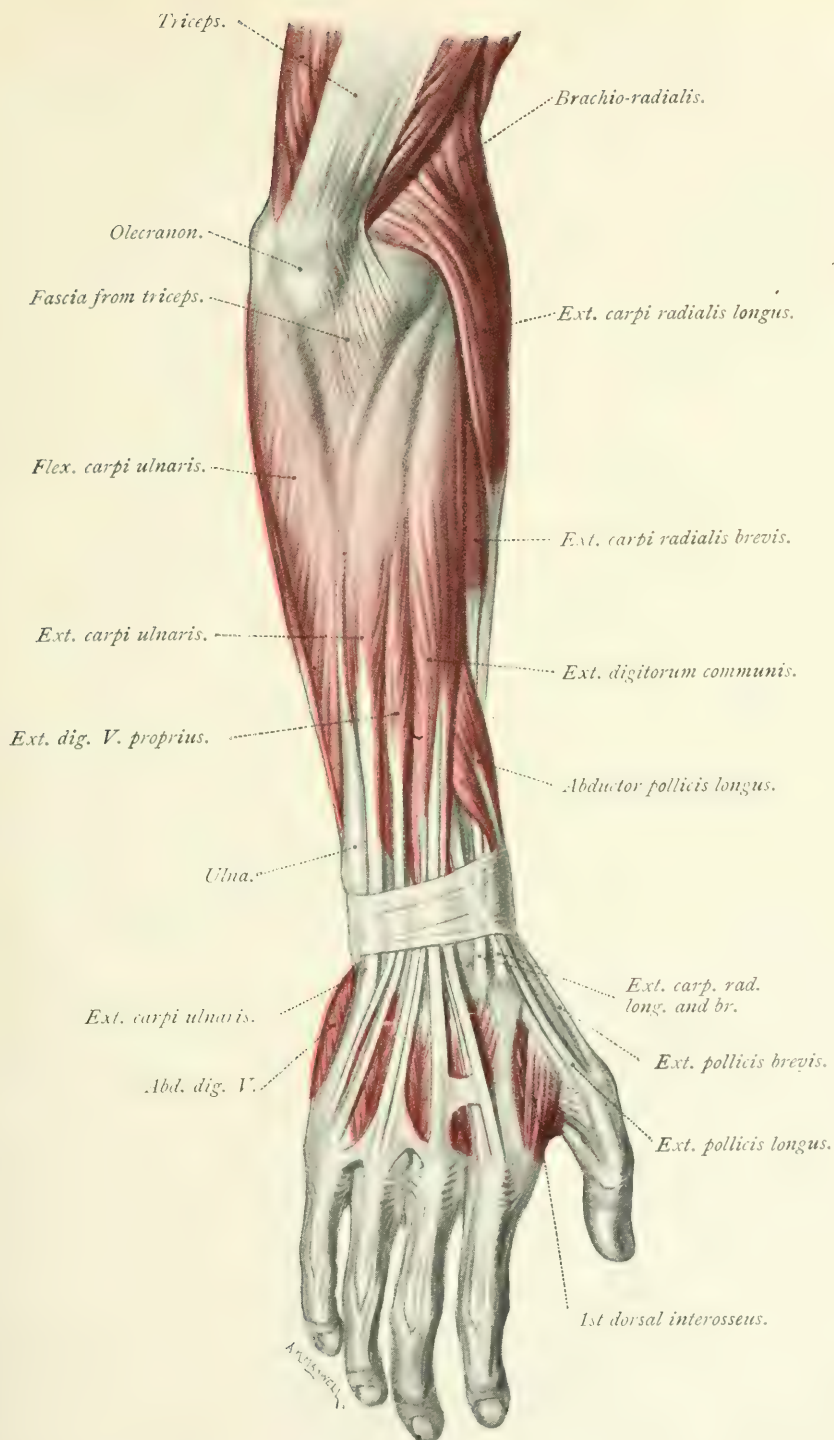


FIG. 52.—MUSCLES OF EXTENSOR ASPECT OF FOREARM, SUPERFICIAL LAYER.

Varieties.—The varieties of the triceps are not numerous, and such as exist are uncommon. The fibres of the long head may be found extending to the capsule of the joint above, or downwards for a greater extent than usual on the axillary border of the scapula. In connexion with the slip of connexion with the latissimus dorsi, a muscular slip may be present which corresponds with the *dorso-epitrochlearis* or *accessorius tricipitis* which is common among anthropoids and exists in some other mammals. An accessory or fourth head has been seen in a few cases, arising from the medial aspect of the humerus above or near the deep head, or from the axillary border of the scapula, from the coracoid process, or even from the capsule of the shoulder-joint. In many cases there is a small bursa above the olecranon either between the tendon of the triceps and the dorsal ligament or more frequently in the deep part of the tendon itself. A bursa placed behind the medial epicondyle beneath the medial edge of the triceps and the ulnar nerve is of rare occurrence.

M. Anconæus (fig. 49).—This small triangular muscle lies at the back of the elbow (fig. 43), beneath the fibrous expansion from the tendon of the triceps, which separates it from the skin. It arises by a narrow tendon from an impression on the lower and back part of the lateral epicondyle of the humerus. The tendon spreads over the anterior surface and along the inferior border of the muscle, and gives origin to muscular fasciculi. These are horizontal above, but becoming gradually more oblique, spread out to be inserted into the lateral aspect of the olecranon, and into the adjacent impression on the shaft of the ulna above the origins of the deep extensors. The proximal fibres are parallel to the distal fibres of the deep head of the triceps, and are generally continuous with them. The deep surface of the muscle is in contact with the supinator muscle and radial collateral ligament of the elbow-joint. A bursa is frequently present between the anconæus and the head of the radius (Whittaker).

Varieties.—The anconæus varies chiefly in being more or less united with the triceps or extensor carpi ulnaris. As stated above, it is to be regarded as a portion of the triceps segmented off in this position. In most mammals it forms a part of this muscle.

Nerve Supply to the Extensor Muscles.—The nerves which supply the triceps and anconæus are derived from the musculo-spiral. The branch to the *long head* arises high up close to the origin of the circumflex nerve. It divides into several twigs, which enter at different levels, the centre of the hilum falling about 11 cm. from the acromion. The *deep head* receives two nerves. One, the *ulnar collateral*, arises high up, has a long extramuscular course, and enters the antero-medial aspect of the muscle by several branches along a vertical hilum, the central point of which falls at 18 cm. below the acromion process. The second nerve arises either independently from the trunk as it passes into its groove, or in common with the branches to the lateral head. It enters the posterior part of the deep head about 18 to 20 cm. below the acromion. The branch to the *lateral head* comes off the trunk before it reaches the spiral groove. It divides into numerous branches which enter the medial side of the muscle. They are so disposed that a line joining the several points of entry is approximately parallel with the main trunk of the nerve. The mean level of the point of entry is 14.62 cm. below the acromion.

The nerve to the *anconæus* comes off with the second nerve to the deep head in the musculo-spiral groove, passes down in the substance of the muscle to reach the anconæus on its deep surface $1\frac{1}{2}$ cm. from the lateral epicondyle of the humerus. The nerve fibres distributed in the various branches to the extensor muscle come from the sixth, seventh, and eighth cervical nerves.

Action of the Muscles of the Elbow-Joint

Since the elbow-joint is a hinge joint, the muscles acting on it may be classified simply as flexors and extensors. The flexor muscle mass exceeds the extensor mass in "moment of contraction" in about the proportion of 14 : 9, this fact in itself accounting for the "contracture" position in hemiplegia. There is a greater difference between the groups in anthropoids, the smallness of the difference being essentially a human characteristic.

The flexor muscles, in the order of the power of their moments of contraction, are: Biceps brachii (two heads), brachialis, brachio-radialis, and pronator teres. To these must be added—though on account of the proximity of their origin to the axis of the joint they are of less significant

value—the flexor and extensor muscles of the wrist which arise from the epicondyles of the humerus.

The part taken by these wrist muscles in flexion of the elbow has been variously stated, but according to Duchenne the flexors of the wrist are auxiliaries to the flexors of the elbow if they are put on the stretch by extension of the wrist. In cases described by Beevor, where the brachialis and the biceps were not acting, the patients in flexing the elbow first pronated the forearm; the extensors of the wrist were then contracted, hyper-extending the wrist, and finally the elbow was very slowly flexed. It was difficult, however, to say whether the elbow flexion was performed by the pronator teres and the flexores carpi, or by the pronator teres and the extensores carpi. The extensor carpi radialis longus, however, should probably be included among the true flexors of the elbow, though it only comes into action when the forearm has already been bent (to 20° of flexion, Fick) by other muscles.

The brachio-radialis, which takes no part in the movement of supination though it acts most powerfully when the forearm is semipronated, is a pure flexor of the elbow and is in action from the commencement of the flexor movement. The brachialis is also a pure flexor. It pulls slightly towards the radial side (Meyer), so that, with the biceps, which pulls somewhat towards the ulnar side, though this tendency may be corrected by the disposition of the lacertus fibrosus, the radius and ulna will tend to be approximated at their upper ends.

Of the other flexor muscles, the biceps is a flexor-supinator and the pronator teres a flexor-pronator. Now flexion of the forearm can be carried out while it is in positions of extreme supination or extreme pronation, or in any position intermediate between these two, so that the muscles which supinate or pronate the forearm, at the same time as they flex, must be in equilibrium as regards the former motions.¹ The pronator teres acts most powerfully as a flexor when the radius is fully pronated, and the biceps about equally strongly in the mid-position and in extreme supination. In extreme pronation the biceps does not seem to contract in weak flexion, that is when no resistance is to be overcome, but acting even against gravity alone the biceps contracts from the commencement of the movement. In practice a greater amount of weight can be lifted by elbow flexion with the supinated hand than with the pronated hand, though the sum of the computed values of the contraction moments of the several muscles is greater in the pronated than in the supinated position. The difference is due to the supinating action of the biceps, which action is carried out before its initiation of flexion can occur, and invariably takes place unless the pronator group (inclusive of the pronator quadratus) is brought into play to neutralise the biceps and to hold the limb pronated.

An interesting combination of muscles is made in the combined movement of supination of the forearm and extension at the elbow, for the biceps then contracts with the triceps, to which it must usually act as an antagonist.

An examination of the values of the moments of contraction of the several muscles at different degrees of flexion shows that at the commencement (0°) of flexion their available work is relatively small: but that the moments of all of them increase in amount till from 95° to 110° of flexion (the weight-bearing angle of the forearm) is reached, from which angle their values decrease (Braune and Fischer).

The extensors at the elbow are the three heads of the triceps and the anconæus muscle. The extensors of the wrist and fingers which arise from the lateral humeral epicondyle can act only in but slight degree (if at all) on the elbow-joint. The supinator muscle acts neither as a flexor nor extensor (Duchenne). Of the heads of the triceps, the lateral is the most powerful, and the long head the least powerful, the availability of the work of the latter depending on the distance between its attachments. When the arm is raised, that is when the distance between its attachments is greatest, it acts to its maximum advantage on the elbow-joint; but if its attachments be approximated as fully as possible, that is, with the arm close to the side, then it is "actively insufficient" even in the greatest contraction of its fibres. Its action on the shoulder-joint is at all times greater than its action on the elbow. The anconæus tends to turn the forearm laterally, or at any rate prevents the upper end of the ulna from moving medially. It will not act as an extensor in full flexion of the elbow, but in this position it rather tends to maintain the flexion (Winslow).

Since the biceps and the triceps may produce movement at the shoulder, that point is fixed by the shoulder muscles, which are therefore fixation muscles for movements at the elbow.

¹ It seems to be well determined that in fractures of the radius below the insertion of the pronator teres, the upper fragment remains in the mid-position between pronation and supination, so that the tonic action of the pronator teres must equal that of the biceps and supinator.

THE MUSCLES AND FASCIÆ OF THE FOREARM

Fasciæ. The **fascia** of the forearm forms, like that of the upper arm, a continuous sheath or investment for the muscles. It is continuous proximally with the fascial sleeve of the arm, distally with the fasciæ of the hand. It is composed principally of transverse fibres, strengthened, however, by longitudinal and oblique fibres descending from the epicondyles of the humerus, from the olecranon, and from the tendons of the biceps in front and triceps behind. Distally in the neighbourhood of the wrist it is reinforced by certain thickenings, which bind down the tendons as they pass over the carpus and are known as the carpal or annular ligaments. The fascial sheath is firmly attached along the dorsal subcutaneous border of the ulna, and along this line the flexor and extensor muscles are sharply divided from one another.

In the proximal part of the forearm, both in front and behind, the fascia is blended with the bundles of tendinous fibres spreading from the epicondyles and the common tendons of the muscles attached to them, so that it appears to give origin by its deep surface to the fasciculi of the muscles over which it lies. It is attached also to the tendinous septa which descend from the common tendons and intervene between the fleshy bellies of the superficial muscles.

In the distal portion of the forearm the partitions between the muscles are more delicate fascial layers, while thin membranes extend transversely and divide the superficial from the deep group of muscles. Each muscle is thus surrounded by a fascial sheath, but the septa between the muscles vary much in thickness, being in many places reduced to planes of delicate areolar tissue. The main arteries which descend through the forearm with their accompanying veins, and in some cases nerves, are also embedded in fascial sheaths. On the anterior aspect of the forearm the fascia is much weaker than on the dorsal aspect. Over the hollow below the bend of the elbow it presents a small oval aperture for the transmission of the deep median vein. Over the muscles descending from the medial epicondyle are seen several white lines marking the positions of the septa between the individual muscles.

The fascia increases in density towards the hand, and a little above the wrist it encloses in a fold the tendon of the long palmar muscle, as it descends on the front of the volar annular (transverse carpal) ligament to be continuous with the narrow end of the palmar aponeurosis. While the superficial muscles are separated by distinct fascial sheaths, the septa intervening between the flexor digitorum sublimus, the flexor digitorum profundus, and the flexor pollicis longus are mere areolar laminae.

Volar Annular or Transverse Carpal Ligament.—The ligament is a strong band somewhat triangular in shape which extends across the front of the hollow of the carpus from the tuberosity of the navicular bone and the ridge of the trapezium on the radial side, to the pisiform bone and hamulus of the hamate bone on the ulnar side.

The ligament proper consists of transverse fibres attached to these bony points, and lies on a deeper plane than the general investing fascia of the forearm. This fascia is carried downwards on the tendon of the palmaris longus and is attached to the volar aspect of the ligament, and binds the tendon to it, while some longitudinal fibres also springing from the distal border of the band extend into the palmar aponeurosis. Further, the distal border and volar surface of the ligament give origin in whole or in part to most of the short muscles of the thumb and little finger. The tendinous fibres from which the two sets of muscles spring cross one another upon it, beneath the more superficial longitudinal fascial fibres. The tendon of the flexor carpi ulnaris gives a slip to the ligament at its proximal border. We have thus—first, a layer of fascia superficial to the ligament, connected with the palmaris longus and surrounding the ulnar vessels and nerves; second, a septum of intercrossing tendinous fibres; and third, a band of deep transverse fibres constituting the ligament proper. The ligament is not fascial in origin. It is developed from the primitive palmar aponeurosis (see p. 27). The aponeurosis acquires

deep attachments to the carpal bones, and certain of the short flexor slips in the hand are attached to the carpus through its agency.

On the radial side some of the deep fibres sweep to the medial side of the tendon of the flexor carpi radialis, to form a special compartment or canal for the passage of the tendon. Through the main compartment under the ligament pass the long flexor tendons surrounded by synovial sheaths which will afterwards be more particularly described.

The fascial investment of the forearm is thicker on the dorsal aspect than on the volar. Just below the elbow it receives a strong expansion from the tendon of the triceps which comes over the anconæus muscle. The tendinous septa derived from the common tendon of the muscles arising from the lateral epicondyle are well marked, and continuous with the investing layer. That between the extensor carpi ulnaris and the extensor minimi digiti is continuous with a distinct fascial septum which reaches the wrist, and separates the muscles along the whole length of the forearm. On the radial side a similar longitudinal septum separates the extensor communis from the extensor carpi radialis brevis.

The **dorsal annular (carpal) ligament**, unlike the volar band, is simply a local thickening of the general fascial investment of the limb. The thickening is effected by a broad band of somewhat oblique fibres which are attached along the lateral aspect of the styloid process of the radius, course medially and also distally over the back of the wrist, and are continued round the medial border of the hand.

The proximal fibres extend over the head of the ulna and triquetral bone to be continuous with the fascia in front, and hence to the front of the volar annular ligament. The more distal fibres extend to the pisiform bone to which they find attachment, and are continued into fibres connected with the tendon of the flexor carpi ulnaris. The deep surface of the ligament is connected to certain longitudinal ridges on the radius, and thus the intermediate grooves are converted into osteo-fibrous canals which lodge the tendons of the extensor muscles.

There are six separate spaces so enclosed, and each is lined by a distinct synovial sac. The most lateral canal corresponds with the groove on the lateral surface of the radius and lodges the long abductor and short extensor of the thumb. The next three, placed on the dorsal aspect of the radius, give passage respectively to the two radial extensors, the long extensor of the thumb, and to the common extensor of the fingers with the extensor of the index finger. Between the radius and ulna is the compartment for the extensor minimi digiti, and on the back of the ulna is the canal for the extensor carpi ulnaris.

Muscles.—From the premuscle sleeve in the middle segment of the limb bud, extensor and flexor masses are laid down, and these very early become divided into superficial sheets arising from the humerus, and deep sheets attached to the bones of the forearm. Each of these sheets then becomes split, by a process of longitudinal cleavage, beginning distally, into the several flexor and pronator or extensor and supinator muscles. It appears, however, that very early, if not from the first, a radial mass, attached to the lateral epicondyle and the humerus above it, is differentiated as a primary division from the extensor mass. It becomes divided into three superficial and (probably) one deep muscle, viz. the brachio-radialis, the two radial extensors of the carpus, and the supinator muscle. It seems proper, therefore, to divide the muscles of the forearm into three groups, each composed of superficial and deep muscles: (1) The volar group of *flexor and pronator* muscles comprising *four* superficial muscles—the pronator teres, flexor carpi radialis, palmaris longus, and flexor carpi ulnaris; and *four* deep muscles—the flexor sublimis and flexor profundus digitorum, flexor pollicis longus and pronator quadratus: (2) The *radial group* comprehending *three* superficial muscles—the brachio-radialis, extensor carpi radialis longus, extensor carpi radialis brevis; and *one* deep muscle, the supinator muscle: (3) The dorsal group

of *extensor muscles* including *three* superficial muscles, *four* if the anconæus be included—the extensor carpi ulnaris, extensor digitorum communis, and extensor minimi digiti proprius; and *four* deep muscles—the abductor pollicis longus, the extensor pollicis brevis, the extensor pollicis longus, and the extensor indicis proprius.

From the point of view of nerve supply the volar group may be again divided into the muscles supplied by the median and those supplied by the ulnar nerve, the first set being further subdivided into those muscles supplied from the trunk of the nerve and those served by its volar interosseous branch. The radial and the dorsal groups are both supplied by the musculo-spiral nerve, the radial group by branches coming off before the nerve pierces the supinator muscle, the extensor group by the deep or dorsal interosseous branch after it has emerged from the muscle.

In the chapter on the general morphology of the muscles, the arrangement of the muscles in a primitive form like one of the Monotremata was taken as a ground plan on which to build the description of the muscles of the forearm and hand. In an early phase such as defined, the flexor and extensor masses show central digital portions and marginal carpal portions. The digital portions consist of superficial long parts rising proximal to the elbow and deep parts fixed to the bones of the forearm. The subdivision of these primitive muscles has resulted in the complex conditions now to be studied

Volar Group—Pronator and Flexor Muscles

M. Pronator Radii Teres (figs. 50, 51).—The pronator teres is the most lateral and the most proximal of the superficial group of muscles. It forms the medial boundary of the antecubital space, and is overlaid by the bicipital fascia. It arises by two heads, one large and superficial, the other smaller and deeply placed. The deep head is not invariably present, and is often tendinous or rudimentary. The median nerve separates the two heads as it enters the forearm. The superficial head springs from the fore part of the medial epicondyle of the humerus, and above this from the medial intermuscular septum, from the common tendon of the superficial group of muscles, and from the tendinous septum which intervenes between it and the flexor carpi radialis muscle. The deep or ulnar head arises from the medial margin of the coronoid process, close to the tendon of insertion of the brachialis anterior with which it is closely connected. It joins the humeral head at an acute angle, and the fleshy belly thus formed proceeds in an oblique direction distally and laterally to end on a flat tendon which turns over the radius and is inserted into a rough impression at the middle of the lateral surface of that bone. The tendon appears on the proximal border and anterior face of the muscle. The superficial muscular fasciculi are continued directly into the tendon fibres, while the distal and deep fibres are inserted at sharp angles into the lateral border of the tendon.

Varieties.—The most interesting variety of this muscle is the extension of the origin in a proximal direction to become attached to a supracondylar process or the ligament which connects this with the epicondyle. In these cases the course of the brachial artery is usually changed. It passes, accompanied by the median nerve, behind the process, deep to the accessory portion of the muscle to reach the antecubital space. Even in the absence of a supracondylar process, an accessory bundle or head may arise from the median intermuscular septum, the humerus, the fascia of the arm, or one of the muscles. As stated already the coronoid head is often absent or rudimentary, but on the other hand it has been seen reinforced by fibres from the front of the ulna. Accessory fasciculi may also connect it with the flexor carpi radialis or flexor sublimis

digitorum. The two heads may be completely separated, and both the coronoid and the humeral heads have been seen divided. The radial attachment may have a more extensive insertion on the radius than usual. In the early embryo the muscle descends to a more distal level than it does in the fully developed arm. This is due to the greater relative growth of the distal part of the shaft of the radius. A very marked ulnar head is present in the monotremes, but is absent in mammals generally, including the lower primates. Among the Simiidae it exists in the orang and chimpanzee but not in the gibbon or gorilla. The muscle was probably originally a flexor, and persists in many animals in which it can act only as such. The deep head probably represents an upper detached part of the original pronator muscle which extended between the bones in the whole length of the arm. The nerve supply by two distinct branches points to its double origin.

M. Flexor Carpi Radialis (fig. 50).—The flexor carpi radialis muscle lies between the pronator teres and the palmaris longus, and immediately under the fascia down to the wrist. It arises from the medial epicondyle by strong fibres forming part of the common tendon, but the muscular fasciculi spring mainly from tendinous septa derived from the tendon which intervene between it and the pronator teres on the one side, the palmaris longus on the other, and the flexor sublimis behind. A few fibres are also derived from the fascia of the forearm covering it. The fleshy fibres end a little below the middle of the forearm on a tendon which appears on the anterior face of the muscle, and on which the superficial fasciculi are arranged in bipennate fashion. The tendon is at first flattened, but soon becomes cylindrical, and reaching the wrist towards the radial side disappears under the volar annular ligament. From the origin on the medial epicondyle to this point the axis of the muscle is directed with a certain degree of obliquity across the forearm. The tendon occupies a special compartment under the ligament, and running through a groove on the trapezium, to which it is bound by a fibrous sheath lined by a synovial membrane, is inserted into the base of the second metacarpal bone, a small slip being generally sent at a considerable angle to the base of the third. A slip is not infrequently also given off to be attached to the ridge on the trapezium. A small independent bursa intervenes between the tendon and the bases of the metacarpal bones.

Varieties.—At its origin the flexor carpi radialis has been observed receiving an additional slip from the tendon of the biceps or its tendinous expansion; from the coronoid process of the ulna, or the anterior oblique line on the radius, as described in gorilla and chimpanzee. Its insertion is subject to frequent variations, the most common being partial or total attachment to the trapezium. It may be also partly inserted into the volar annular ligament or the navicular bone, and the supplementary slip to the third metacarpal may be extended to the fourth. Absence of the muscle has also been met with.

M. Palmaris Longus (fig. 50).—The long palmar muscle is a particularly variable muscle, and is frequently absent. It belongs to the class known as retrogressive muscles, and along with the palmar aponeurosis represents the most superficial portion of the primitive common flexor. A powerful flexor in lower tetrapodal vertebrates, it becomes retrogressive as the deep flexor assumes the dominant rôle (see p. 28). When present in a form which may be considered normal, it arises by long tendinous fibres from the angle of the medial epicondyle, from the septa between it and the adjoining muscles, and slightly from the fascia of the forearm. The fleshy belly, which is slender and fusiform, ends in the middle third of the forearm in a long and slender tendon placed on the medial side of, and running parallel to that of the flexor carpi radialis. It is superficial throughout its whole course. In the distal part of the forearm, above the wrist, the tendon is enclosed in a duplicature of the fascia of the forearm. On reaching the volar annular ligament it broadens out and ends in the palmar aponeurosis, but often sends a slip to the abductor pollicis muscle. The lateral

fibres of the expanded tendon are delicate and spread over the thenar and hypothenar eminences; the central fibres, much stronger, form the main longitudinal bundles in the aponeurosis.

Varieties.—This is probably the most variable muscle of the body. It is absent in 11·2 per cent. of bodies, according to the results collected from all sources by Le Double. It is subject to many variations in form. It may be fleshy in its whole length. It may have a proximal tendon as well as a distal one; it may be fleshy distally and tendinous proximally; or it may be reduced to a mere tendinous band. Occasionally there are two long palmar muscles, one having the normal form, while the other has one of the forms referred to, or one of the additional modes of origin next mentioned. The muscle may arise from the medial intermuscular septum, the biceps or brachialis anterior, the fascia of the forearm high up or low down, one of the neighbouring muscles, the coronoid process, or the radius. Again the muscle may be double at its proximal end, the additional slip arising from one of the situations indicated. The insertion of the muscle is equally variable. Thus it may be attached to the fascia of the forearm, the tendon of the flexor carpi ulnaris, the volar annular ligament, the pisiform bone, the navicular bone, the short abductor of the thumb or muscles of the hypothenar eminence, or one of the flexor tendons. Its tendon of insertion may be split into two or more bundles, in which case the accessory slip or slips may be inserted into one of the parts named.

M. Flexor Carpi Ulnaris (figs. 50, 54).—This muscle is the most medial of the superficial group, and lies along the ulnar border of the forearm, immediately under the fascia. It arises by two heads, the one from the humerus, the other from the ulna. Between the two heads the ulnar nerve and ulnar recurrent artery occupy the groove between the medial epicondyle and the olecranon process. The *humeral head* springs by tendinous fibres, which form the back part of the common tendon, from the extremity and lower part of the medial epicondyle. The *ulnar head* arises from the medial border of the olecranon process, and the dorsal border of the ulna for the upper two-thirds of its length by an aponeurosis which is inseparably united with the investing fascia of the limb. The two heads are united over the groove for the ulnar nerve by a tendinous arch uniting the olecranon process with the epicondyle. The tendon which is developed in the substance of the muscle appears, about the middle of the arm, on its anterior border. The muscular fibres connected with the humeral head descend in a vertical direction; those arising from the ulna course obliquely, and are arranged pennately on the tendon, which does not become free of fleshy fasciculi until close to its insertion into the pisiform bone. The insertion is not confined to this bone, but is continued to the base of the fifth metacarpal bone and the hamulus of the hamate bone by the *pisi-metacarpal* and *pisi-hamate* ligaments respectively. A small slip also passes to the volar annular ligament, and other fibres are continuous round the medial border of the wrist with the dorsal annular ligament. A small bursa is occasionally to be found between the tendon and the pisiform bone.

Varieties.—In a case described by Froshe and Fränkel the anterior fibres of the muscle formed an accessory muscle which only joined the main belly below the middle of the forearm. It was supplied not by the ulnar, but by the median nerve. From the complete independence of the two branches usually given by the ulnar nerve the same authors suggest that the muscle is formed of two elements fused with one another. An additional slip of origin from the medial side of the coronoid process is often present. It would appear, therefore, that elements of the digital flexor mass are sometimes included in the flexor carpi ulnaris. The ulnar head as the marginal ulnar component is a constant muscle from the amphibians upwards, but the humeral head is acquired and probably represents a contribution from the common digital mass. Partial insertion into the volar annular ligament has been recorded, and the attachment to the fifth metacarpal may extend to the fourth or even the third metacarpal bone by the prolongation radialwards of the pisi-metacarpal band of fibres. Extension of the fibres to the capsule of the fifth metacarpo-phalangeal joint has been observed, as has also the occurrence of a slip connecting the tendon with the abductor of the little finger.

The *epitrochleo-anconeus* is a small aberrant muscle which may be mentioned at this point.

It arises from the back of the medial epicondyle and is inserted into the olecranon process. It lies over the ulnar nerve from which it receives a twig. It is perhaps represented normally by a band of transverse fibres in the fascia.

M. Flexor Digitorum Sublimis, or Flexor Perforatus (figs. 50, 54).—The superficial flexor of the fingers is developed by delamination from the deep flexor mass of the forearm, and lies deep to the preceding muscles. It arises from the anterior face of the medial epicondyle of the humerus by a thick, strong tendinous head, and septal prolongations of this between it and the adjoining muscles, from the medial collateral ligament of the elbow-joint, and from the medial margin of the coronoid process of the ulna. To this large ulnar head is added a radial head in the form of a thin, flat portion arising by short tendinous and fleshy fibres, from the volar border of the radius and its proximal oblique continuation. The two heads unite on a fibrous arch under which the median nerve and deep vessels pass. The muscle divides distally into four parts, ending in as many tendons, which pass to be inserted into the second phalanges of the second, third, fourth, and fifth digits. For the proper understanding of the muscle the following detail must be noted.

The thick ulnar head is easily separated into two lamellæ, a superficial and deep, close up to the origin from the epicondyle. The superficial part springs from the epicondyle by a tendinous lamella which forms part of the common tendon, and is continuous with the radial head. It is divided longitudinally into two bellies, ulnar and radial. The ulnar belly consists of muscular fasciculi which end pennately on the tendon which goes to the ring finger; the radial belly, mainly derived from the radial head, is composed of fasciculi which terminate, also in a penniform fashion, on the tendon which goes to the middle finger. These two tendons lie side by side under the volar annular ligament of the wrist on a more superficial plane than the tendons to the second and fifth fingers, which belong to the deep lamella of the muscle. This has a broad origin for the most part by fleshy fibres from the medial epicondyle, the medial collateral ligament, and the coronoid process, as well as from the deep surface of the tendon of the superficial lamella and the adjacent margin of the epicondylar tendon of the flexor carpi ulnaris. The fleshy fibres form a conical belly, which ends on a flat cylindrical tendon above the middle of the forearm. From this tendon again another fleshy belly arises, the fasciculi of which end upon the tendon which goes to the index finger, while on the ulnar side a small slip is given off which provides the tendon to the little finger. The deep lamella has thus the form of a digastric muscle. In a large percentage of subjects a slender fasciculus passes from the radial side of the epicondylar-ulnar part of the superficial lamella to the beginning of the tendon of the flexor pollicis longus. It may be added also that often a slip is given from the deep lamella to the tendon to the ring finger.

After passing under the volar annular ligament in the position already indicated, the tendons diverge from one another in the palm of the hand, and each, accompanied by a tendon of the deep flexor, enters a fibrous sheath which binds down both tendons to the palmar surfaces of the phalanges. Opposite the first phalanx the tendon of the flexor sublimis becomes flattened and divides into two parts, which fold closely round the rounded tendon of the deep flexor. The two slips are again united behind the deep tendon by the margins, which were the free borders of the undivided tendon, and finally separating once more from one another, pass to be inserted opposite the middle of the shaft of the second phalanx into the ridges at the lateral borders of its volar surface (fig. 46). The fibrous digital sheaths for the tendons will be dealt with later along with the palmar fascia (p. 149).

Varieties.—As has been already noted the flexor digitorum sublimis is derived by delamination from the deep flexor mass. This separation does not occur in lower tetrapodal vertebrates (see p. 27), and even in mammals there is often a certain amount of blending of the layers. All the varieties to be mentioned are explicable when the history of the muscle is considered. Varieties occur which may be termed retrogressive in that they represent survivals of the connexions between the two sheets. Thus a slip (already mentioned) very frequently connects the sublimis with the

long flexor of the thumb; muscular slips occasionally pass between the superficial and deep flexors of the fingers; sometimes a muscular slip derived from the sublimis, or direct from the coronoid process, ends on a tendon which joins one of the tendons of the deep flexor (*accessarius profundus digitorum*); tendinous slips not infrequently connect the tendons of the two muscles. On the other hand, the occasional separation up to their origins of the individual muscular bellies may be considered a progressive variation. The extensive origin of the muscle from the radius is a human feature. The radial head shows much variability as might be expected from this circumstance. Its complete absence has been noted, a reversion to the condition seen in certain of the anthropoids. One or other of the distal divisions of the muscle may be deficient. The commonest instance of this is the absence of the belly for the little finger. Normally this is the smallest division of the muscle, and it arises from the side of the intermediate tendon of the deep portion. In the absence of the fourth belly, its place may be taken by a belly arising from the medial collateral ligament of the ulna, from the deep flexor, from the transverse carpal ligament and palmar aponeurosis, or the ligament alone, or by the fourth lumbrical muscle. From the superficial aspect of the muscle a slip has been seen passing to the palmaris longus, or replacing it if absent, and then ending in the fascia of the forearm, or palmar aponeurosis. A slip (*M. radio-palmaris*) may be present arising direct from the radius beneath the sublimis and attached to the palmar aponeurosis or the common sheath of the flexor tendons. A certain amount of variation occurs in the origin of the tendons from the muscle, thus a slip from the deep part of the muscle in some cases forms the chief part of the ring finger division; or there may be a slip from the deep part to the middle finger tendon; or again the radial head has been seen supplying the tendon to the fourth digit, that for the third springing from the extreme radial part of the radial head only and reinforced by a tendon arising from the epicondyle. An accessory slip is sometimes present passing from the tuberosity of the ulna to the index and middle finger portions. Very rare are instances in which the whole muscle is "digastric"; cases in which the medial and lateral tendons are absent and replaced by a sheet of muscle representing a second superficial flexor; and instances of failure of the tendon to divide within the flexor sheath.

Relations.—In the forearm the flexor sublimis is for the most part concealed by the pronator teres, flexor carpi radialis, and palmaris longus muscles. Between the last-named muscle and the flexor carpi ulnaris a narrow slip is superficial from the medial epicondyle distalwards to the volar annular ligament. The radial head is crossed by the radial vessels. It rests on the flexor pollicis longus and the flexor digitorum profundus. The median nerve, which passes between its two heads, and the ulnar vessels lie between it and the flexor profundus. In the palm of the hand its tendons are covered by the palmar aponeurosis, the superficial palmar arch, and the branches of the median nerve, and they lie superficial to the tendons of the flexor profundus.

M. Flexor Digitorum Profundus, or Flexor Perforans (fig. 51).—The deep flexor of the fingers and the long flexor of the thumb constitute the second stratum derived from the deep flexor mass.

The flexor digitorum profundus, a large and thick muscle, lies on the ulna and interosseous membrane under cover of the flexor carpi ulnaris and flexor digitorum sublimis. It arises from the medial and volar surfaces of the ulna for three-fourths of its length, from the aponeurosis attaching the flexor carpi ulnaris to the dorsal border of the bone, and from the interosseous membrane. On this its lateral border comes into contact with the long flexor of the thumb, and there is often a slip from the proximal part of the radius close to the membrane. The proximal extremity of the muscle embraces the insertion on the coronoid process of the brachialis anterior. The fleshy mass, continuous above, shows distally a partial separation into four bellies which give origin to four tendons, only one of which, that for the index finger, is distinct from the others above the wrist, the rest being connected together as far as the palm. The index finger portion of the muscle is usually independent to a considerable extent, and springs mainly from the interosseous membrane and slightly from the ulna. The middle and ring finger portions arise, in close connexion, from the volar and medial surfaces of the ulna, the aponeurosis near the elbow, and slightly from the interosseous membrane distally. The little finger portion comes from the back part of the medial surface of the bone and the aponeurosis of the flexor carpi ulnaris.

The tendons pass under the anterior annular ligament behind those of the

superficial flexor, and reaching the palm separate from one another, and give origin to the lumbrical muscles. Each tendon, when it reaches the finger to which it belongs, enters the digital sheath, deep to the corresponding superficial tendon. Opposite the first phalanx it passes through the opening formed for its transmission in the superficial tendon, and is inserted into the base of the distal phalanx by a small terminal expansion.

Varieties.—In lower mammals this layer consists ideally of five portions: *radialis* (flexor pollicis longus), *ulnaris* (flexor digitorum profundus), the *condylo-ulnaris*, *condylo-radialis*, and *centralis* (Windle). Of these factors only the first two appear as separate entities in man; the other parts may possibly be represented by certain abnormal slips, or are perhaps taken up into the sublimis (M'Murich). The various modes in which the superficial and deep flexors may be united have already been noted under the head of the flexor digitorum sublimis. In addition a connexion with the flexor pollicis longus is not infrequent, generally in the form of a slip passing from that muscle to the index finger tendon of the deep flexor. The separation of the index finger tendon from the others is a distinctly human character, and is to be correlated with the specialisation of the index finger. The degree of isolation varies; it may be quite independent, forming a *flexor indicis profundus*. The radial origin has been seen extending a considerable distance on the bone alongside the long flexor of the thumb, and a muscular slip has been described arising from the radius above the pronator radii teres and joining the muscular belly below. Mention must be made again of a muscular slip (*accessorius profundus digitorum*) which arises from the coronoid process and ends on one or other of the tendons of the muscle.

M. Lumbricales (figs. 50, 51, 54).—These are four tapering fleshy fasciculi, which pass from the tendons of the flexor profundus to the tendons of the common extensor muscle. Each lumbrical arises by fleshy fibres from the radial border of the tendon to which it belongs, and in the majority of instances this is the sole attachment of the first and second muscles. In the case of the third and fourth lumbricales, however, there are additional attachments to the ulnar sides of the second and third tendons; in short, they arise bipennately from the tendons between which they are placed. The lumbricales, especially the first, tend to overlap at their proximal ends the tendons of the superficial flexor, seeming at first sight to arise from them. Each muscle, when it reaches the level of the metacarpo-phalangeal joint, proceeds dorsalwards, ensheathed in fascia, to be inserted, on the radial side of the finger and by a delicate flat tendon, into the expansion of the extensor tendon on the proximal phalanx. This is always true of the first and second lumbricales, but the third and fourth are frequently bifid and are attached to the adjacent sides of the fingers between which they lie.

Varieties.—The lumbrical muscles show frequent variations from what is above described as the typical condition. They may be reduced to three or even to two, and rare instances have been recorded of an absence of all four. On the other hand, also in rare cases, the number may be increased by the development of accessory slips, or the fission of the muscles. In the case of the first the accessory slip may arise from the tendon of the flexor pollicis longus, from the tendon of the flexor sublimis, from the first metacarpal, or opponens pollicis. Cases have been observed also in which a fasciculus arose from the muscular belly of the superficial or of the deep flexor and was continued into the first lumbrical muscle. The second lumbrical may arise from both the tendons between which it lies. On the other hand, the third and fourth may arise from one tendon only. The origin of one or other of the lumbricales may be displaced proximally; arising then from the volar annular ligament, or by a special tendon from the deep or superficial flexor, or in the case of the first from the tendon of the flexor pollicis longus. They may be attached in the palm to the superficial as well as to the deep flexor tendons. Not infrequently the lumbrical muscles may be bifid distally, and come to be inserted into two fingers. This occurs in the case of the third lumbrical in about 40 per cent. of individuals.

The destination of one or other of them otherwise normal may be changed, and one finger has sometimes two inserted into it. They may be inserted into the first phalanx instead of, or in addition to, the normal attachment to the extensor tendon. The fourth has been observed to take the place of the fourth perforated tendon of the flexor sublimis. Many of these varieties, but more especially the cleavage so that a finger may have a lumbrical attached to its extensor

tendon on either side, are of interest in connexion with the arrangement of the lumbricals in lower forms. It is probable that originally there were two lumbricals to each digit.

M. Flexor Pollicis Longus (fig. 51). The long flexor of the thumb, the radial division of the deep flexor sheet, arises from the volar aspect of the radius, from the pronator teres to the proximal border of the pronator quadratus muscle, and from the adjacent part of the interosseous membrane, coming here in contact with the radial border of the flexor digitorum profundus. It is separated from the pronator teres by the radial head of the flexor digitorum sublimis, and lies under cover of that muscle in its proximal part. Distally, placed between the brachio-radialis and flexor carpi radialis which overlaps the muscle from the ulnar side, it supports the radial vessels. In the majority of instances it receives a distinct fleshy and tendinous slip springing, in common with the flexor digitorum sublimis, from the coronoid process or medial epicondyle, or from both. The fleshy fibres are inserted pennately on a tendon which appears along the ulnar border of the muscle, close to the index tendon of the deep flexor of the fingers. The tendon, which does not become free of muscular fasciculi till the level of the carpus is reached, crosses the pronator quadratus and passes behind the volar annular ligament, close to the trapezium. It then inclines laterally, and passing between the two sesamoids of the metacarpo-phalangeal joint, finally enters a fibrous sheath similar to those of the other flexor tendons, and ends in an expansion on the base of the terminal phalanx of the thumb.

Varieties. --In a complete and separate form the flexor pollicis longus is characteristic of man. Only in the gibbon among the Simiidae is it in some measure independent. In the orang, chimpanzee, and gorilla it is very variable and may be absent or form part of the deep flexor of the fingers. In the lower primates there is only one common deep flexor which gives a well-marked tendon to the thumb. In some cases that have been recorded, this condition is exactly reproduced in man; in others the muscle is fused with the index tendon of the flexor profundus as occurs in the gorilla and chimpanzee. The fact that in *Tarsius spectrum* the muscle belly and tendon are separate, and nearly realise the human condition, indicates that perhaps the partial development of the muscle in the anthropoids may be a degeneration from the primitive type (Wood Jones). The tendon has been seen giving a second tendon to the index finger, and it also may give a slip to the first lumbrical muscle. Fleshy slips are sometimes present uniting the belly of the muscle to the flexor digitorum sublimis, or profundus. These and the humeral and coronoid heads above described are further indications of the original connexion between the divisions of the deep flexor sheet. The accessory coronoid head is subject to some variation, being occasionally divided distally into two or three slips passing to the flexor pollicis longus, to the flexor digitorum profundus, flexor sublimis, or pronator teres. This last muscle may give some fasciculi to the flexor of the thumb. The coronoid head possibly represents the element of the deep flexor of lower mammals named by Windle the condylo-radialis, while the accessorius profundus, according to the same authority, corresponds to the centralis.

M. Pronator Quadratus (figs. 51, 54).—The deep pronator is placed close to the bones behind the last two muscles. As its name indicates, it is quadrilateral in shape, and it is thicker in its distal than at its proximal part. It arises from the pronator ridge and adjoining ulnar part of the volar surface of the ulna in its distal fourth, by deep fleshy and a layer of superficial tendinous fibres. Its fasciculi cross the distal part of the forearm transversely, and are inserted into the volar surface and medial face of the radius, on its distal fourth, extending downwards so as to overlap the greater part of the distal radio-ulnar joint. The muscular fasciculi are mainly horizontal on the volar aspect of the muscle, but there are deep bundles of oblique fibres which occupy its dorsal face. Distally the deeper bundles go to the medial face of the radius, whereas in the more proximal part of the muscle the fasciculi extend between the volar surfaces and borders of the bones. This accounts for the increased thickness of the muscle near its distal border.

Varieties.—In very rare instances when the radius is normal the absence of a pronator quadratus has been noted. It is occasionally laminated into two or more layers consisting of fasciculi running in different directions. It may be continued down on the carpus, in some cases as a radio-carpal, in other cases as an ulno-carpal fasciculus. It may extend also in a proximal direction on the radius, so as to be connected with the pronator teres; this variety is of interest in view of the fact that the two pronators form one muscle in most lower mammals. The upper part has become separated from the lower part by the falling out of the intermediate portion of the primitive muscle mass. The two parts are closely related on the radius in early stages of development. They seem to be drawn apart by the greater relative growth of the distal end of the radius. Its shape may be triangular, the apex of the triangle on the radius, a condition reminiscent of the form of the muscle in the Simiidae.

Two accessory muscles in this region may be described at this point. The *radio-carpeus* or *flexor carpi radialis brevis* is a small penniform muscle not infrequently met with, which arises from the radius, usually from its volar border and surface proximal to the pronator quadratus, but may extend proximally even to the ulna or medial epicondyle and have other attachments. It is inserted by a tendon on one or more carpal bones or one or more metacarpals, or both at once. The *ulno-carpeus brevis* is a small muscle, of rare occurrence, corresponding to and resembling the radial muscle. It arises from the ulna, on its medial or volar surface, and is inserted into the pisiform bone, the hamulus or fifth metacarpal, the capsule of the carpal articulation, or the abductor digiti quinti.

Nerve Supply to the Volar Group of Muscles.—The pronator teres, flexor carpi radialis, palmaris longus, and flexor digitorum sublimis receive their branches of supply from the trunk of the median nerve, while the volar interosseous nerve supplies the flexor pollicis longus, part of the flexor digitorum profundus, and the pronator quadratus. The flexor carpi ulnaris and the other moiety of the flexor digitorum profundus are supplied by the ulnar nerve.

The nerve to the *pronator teres* comes off the trunk of the median in the bend of the elbow, sometimes above, sometimes behind the muscle. It divides into two branches, which however may arise independently, one for the humeral head, the other mainly but not entirely for the coronoid head. The upper twig enters the radial side of the muscle just below the level of the medial epicondyle and at a point about 3 cm. from it. The lower branch runs along the radial border of the muscle and enters its deep surface lower down near its insertion. The nerve for the *flexor carpi radialis* is the highest of a sheaf of branches which come off the median trunk at the upper border of the flexor sublimis and supply the superficial layer of muscles. It pierces the origin of this muscle, runs medially and distally, and divides into two or more branches which enter the deep surface of the muscle, in the proximal third of the forearm, about 6 to 8 cm. down the muscle from the medial epicondyle. The nerve to the *palmaris longus*, after arising in common with the last, pierces the flexor sublimis, and enters the deep surface of its muscle at a variable level, sometimes (Froshe, Cohn, Reid) at a higher level than the nerve to the flexor carpi radialis, sometimes at a lower level (Linell). The *flexor digitorum sublimis* receives three nerves, two which come off the median trunk in the proximal third, and one which arises about the middle of the forearm. The uppermost twig goes to the proximal belly, the lowermost twig to the distal belly of the deep digastric flexor of the index finger. The second upper branch supplies the remainder of the muscle, *i.e.* the superficial part which goes to the third and fourth fingers, and the deep slip to the little finger. The uppermost twig enters the muscle about 3.5 cm. from the medial epicondyle, the second a little lower, 7 cm. The lowest branch comes off the trunk at a variable level, but so much lower down that the flexor indicis may be the only part of the muscle affected in an injury to the median nerve in the forearm. It enters its muscle a little below the middle of the forearm about 15 cm. from the medial epicondyle. According to Froshe, the upper deep part of the muscle may in rare cases receive a twig from the ulnar nerve. The *flexor carpi ulnaris* receives its nerve supply from a series of branches, two, three, or even four, which come off separately or conjoined in one branch, from the ulnar nerve high up at the elbow. The two most proximal of these twigs come off as the nerve lies in its groove and before it passes between the heads of the muscle; the first after a short course enters the olecranon head about 2.5 cm. from the medial epicondyle; the second arises just below the first, and enters the humeral head about 3 cm. from the medial epicondyle. A third branch not always present arises at a slightly lower level, has a considerably longer extramuscular course, and enters the humeral head several centimetres lower down. Within the muscle the twigs belonging to each of the two main branches communicate with one another, but not with those of the other branch (Froshe). Froshe shows a supply of a small part of the muscle by a twig from the median nerve. The ulnar supply to the *flexor digitorum profundus* is given by a branch which comes off the ulnar trunk high up in the upper fourth of the forearm. It is a stout branch which runs on the surface of the muscle to enter its substance about 5 to 6 cm. below the epicondyle. It supplies the larger and more undivided part of the muscle which gives tendons to the fifth, fourth, and third fingers.

The supply from the median nerve comes from the volar interosseous branch by a stout twig arising near the origin of the main interosseous trunk, and several smaller ones given off from the nerve as it lies on the interosseous membrane. These branches mainly go to the index finger portion of the muscle, and the main anatomical muscle hilum is placed at about 10 cm. from the medial epicondyle. One filament from the main branch sometimes joins a twig from the ulnar and is distributed with it to the middle finger portion. Thus the index finger portion is supplied wholly by the median, the fourth and fifth finger portions solely by the ulnar, while the third finger portion may have a double supply. The *lumbricals* are supplied, the two radial by the median, the two ulnar by the ulnar nerve. The twigs from the median are given off from the digital branches, and enter the muscle on their volar aspect; the ulnar twigs come from the corresponding branches of the ulnar nerve and enter the deep faces of their muscles. As in the case of the main muscle mass there is a tendency to overlapping of the fields of the two nerves, the third lumbrical being not infrequently supplied by twigs from both median and ulnar nerves. The main nerve to the *flexor pollicis longus* comes off from the volar interosseous about the same level as that for the *flexor profundus*. It divides into two branches, which however may arise separately. These are distributed in the substance of the muscle, one to each portion of the bipennate belly. The point of entry lies from 10 to 11 cm. below the median epicondyle. The *pronator quadratus* is supplied by the terminal branch of the volar interosseous nerve, which reaches it on its dorsal aspect, about its middle. It divides into several branches before it enters the muscle substance, and these are distributed proximally and distally. The point of entry may be indicated in an arm of average length by a point 4.5 cm. from the styloid process of the radius and 3.5 cm. from that of the ulna.

Radial Group of Muscles

The muscles included in this group, representing the subdivision of the primitive radial carpal extensor, are the brachio-radialis, the two extensors of the carpus, and the supinator muscle. All are supplied by the musculo-spiral nerve, direct from the trunk or by branches coming off before the deep radial (dorsal interosseous) branch has passed through the supinator muscle.

M. Brachio-Radialis (figs. 50, 51, 52).—This muscle occupies the radial side of the forearm and overlaps the flexor group in front, being in deep contact with part of the pronator teres and flexor sublimis muscles, as well as the supinator, the deep muscle of the group. It overlaps posteriorly the long extensor of the carpus and lies under skin and fascia throughout, except at its insertion where it is crossed by the tendons of the extensors of the thumb. It arises from the proximal two-thirds of the lateral epicondylar ridge of the humerus, and from the intermuscular septum between it and the lateral head of the triceps. It is in close apposition to the brachialis anterior medially, the musculo-spiral nerve intervening. The fasciculi form a thin fleshy mass which is to a certain extent turned upon itself as it passes down on to the forearm, where it forms the lateral boundary of the antecubital space. The fasciculi end about the middle of the forearm on a flat tendon, which is inserted into an impression on the lateral face of the distal end of the radius near the base of the styloid process.

Varieties.—The brachio-radialis is often united with the brachialis anterior at its origin, and may extend upwards as far as the insertion of the deltoid, with which it may also be connected. The muscle may be divided, the second belly finding attachment distally to the radius in the neighbourhood of the tuberosity, or even to the ulna. The tendon is occasionally cleft into two or three slips, and a slip may also proceed to the fascia of the forearm. The insertion may ascend on the lateral face of the radius, or may be extended distally to the navicular, trapezium, or the base of the third metacarpal bone.

M. Extensor Carpi Radialis Longus (figs. 50, 51, 52).—The long radial extensor of the carpus arises from the lateral epicondylar ridge distal to the brachio-radialis, also from the lateral intermuscular septum and epicondyle itself by fibres connected with the common tendon of the extensor muscles. The muscular

belly, prismatic in form, lies in close relation to the external part of the capsule of the elbow-joint, is overlapped by the brachio-radialis, and in turn overlaps the short radial extensor. The fasciculi end, about the junction of the proximal and middle thirds of the forearm, upon a broad flat tendon which is applied to the outer face of the short radial extensor and its tendon, being bound to the latter by a layer of connective tissue. The two tendons descend together under the fascia of the forearm, are crossed over by the abductor pollicis longus and extensor pollicis brevis muscles, a large bursa being interposed between. Then, still side by side, they pass through a common osteo-fibrous canal under the dorsal annular ligament, and reappearing again distal to the ligament, are crossed by the tendon of the long extensor of the thumb. The tendon of the long carpal extensor is inserted into the base of the second metacarpal bone. A small bursa is occasionally found under the tendon near its insertion.

M. Extensor Carpi Radialis Brevis (figs. 51, 52). The short radial extensor arises from the lateral epicondyle by a strong bundle of tendinous fibres which form part of the common tendon, from the fibrous septum between it and the extensor communis digitorum and from the fascia covering it. The muscular belly which has a prismatic form descends to about the middle of the forearm, under the long radial extensor and in deep contact with the supinator muscle, a bursa sometimes intervening, and with the insertion of the pronator teres. The fasciculi converge on a flat tendon which appears high up on the lateral face of the muscle, and is, down to the wrist, closely applied to that of the extensor carpi radialis longus. Descending, as already explained, with the tendon of this muscle, and passing under the posterior annular ligament, it appears below the ligament, is crossed by the tendon of the long extensor of the thumb, and is inserted into the base of the third metacarpal bone. There is a small bursa between the tendon and the styloid process of the metacarpal.

Varieties.—In lower mammals the two extensores carpi radiales are represented by one muscle, and in the human subject cases have been noted in which the muscles were fused, the common belly having two or three tendons inserted into the metacarpal bones. Incomplete fusion frequently occurs effected by cross slips from one muscle to the other. These connecting fasciculi may be replaced by distinct muscles connected with one or both of the radial extensors. The name *extensor carpi radialis intermedius* is given to a rare muscle which arises independently from the epicondyle of the humerus between the two normal muscles and is inserted into the second and third metacarpal bones. More frequently the accessory muscle is represented by a slip from one or both of the radial extensors and is inserted, in the same way, into the second or third metacarpal or both of these bones. The *extensor carpi radialis accessorius* (Wood) is another additional muscle sometimes met with, arising from the humerus with or below the long radial extensor, and inserted most frequently into the metacarpal bone of the thumb, but sometimes into other parts. It is represented at times by a slip from the tendon of the extensor longus.

The radial extensors may be divided in their fleshy parts, but much more commonly it is one of the tendons that is split into two or sometimes three tendons previous to insertion. Both tendons may then be attached to the second and third metacarpal bones. Occasionally a slip passes also to the fourth metacarpal.

M. Supinator (figs. 51, 53).—This muscle is here described as the deep member of the radial group of muscles. It surrounds the neck of the radius, and lies under the brachio-radialis, the two radial extensors, and the other extensor muscles arising from the lateral epicondyle. Its volar surface forms the radial side of the floor of the antecubital space. Thus deeply situated it arises *first* by a tendinous head intimately connected with the common tendon of the extensor group of muscles, from the radial collateral ligament of the elbow-joint and annular (orbicular) ligament; *second*, by superficial tendinous fibres from the supinator ridge, and by fleshy fibres from the hinder part of the bicipital hollow below the

radial notch of the ulna, extending a short distance down the interosseous crest of the bone. The fleshy fibres derived from these points of attachment, as well as from the tendinous expansion on the surface which can be followed up to the epicondyle, pass obliquely round the proximal part of the radius, and are inserted into it except on its medial aspect. The area of attachment extends for rather more than a third of the length of the radius, reaches down to the insertion of the pronator teres laterally, and is limited in front and behind by the oblique lines which ascend on the volar and dorsal surfaces of the bone. The muscle thus forms a lozenge-shaped sheet of no great thickness, completely investing the neck of the radius. It is pierced in an oblique direction by the deep radial branch of the musculo-spiral nerve, which effects a more or less complete division of the muscle into two layers.

Varieties.—The division of the muscle into two lamellæ may be more pronounced than is normally the case; an accessory fasciculus from the lateral epicondyle has been observed, also fibres inserted into the tendon of the biceps, the bursa under that tendon, and the tuberosity of the radius. Detached bundles of the muscle, both in front and behind, attached to the annular ligament have received special names, but there is no reason to regard them as separate factors in the muscle.

Nerve Supply of the Radial Group of Muscles.—The *brachio-radialis* receives one or more twigs from the musculo-spiral nerve about the level of the elbow-joint. There is a minute proximal branch which enters the upper part of the muscle. The main branch runs for a considerable distance on its ulnar face before entering the muscle substance at a point on the muscle about 3 cm. below the lateral epicondyle. The nerve to the *long radial extensor* comes off about the same level, and breaks up into medial and lateral branches, which, after a short extramuscular course, enter the muscle on its deep surface well above its middle (about 2.5 cm. below the lateral epicondyle), and freely join with one another in the substance of the muscle. A minute twig is sometimes given off from the main nerve above the epicondyle as high as the origin of the *brachio-radialis*. The *short radial extensor* is supplied by a branch which comes off lower down, either from the anterior division of the nerve or the deep division before it reaches the supinator muscle. It runs along the ulnar border of the muscle, and gives off several (three or more) twigs which enter the muscle along this border 7 to 9 cm. below the lateral epicondyle. The *supinator muscle* receives its supply by two or more twigs which come off from the deep branch of the musculo-spiral as it enters the cleft between the two layers of the muscle. In a dissection by Mr Cappell in which the muscle was distinctly divided into two separate portions, two branches were given off: (a) one to the deep surface of the superficial portion on which it ended in a number of filaments which spread out in a cone-shaped manner over a small triangular area; (b) one to the deep portion which gave off a series of lateral branches in the more usual fashion.

Dorsal Group of Muscles

This group of muscles includes the anconæus already described, three superficial muscles—the extensor digitorum communis, extensor minimi digiti, and extensor carpi ulnaris; and four deep muscles—the extensor indicis proprius, abductor pollicis longus, extensor pollicis brevis, and extensor pollicis longus. All these muscles are supplied through the musculo-spiral nerve by means of twigs of its deep or dorsal branch, given off after that branch has pierced the supinator muscle.

M. Extensor Digitorum Communis (fig. 52).—The common extensor of the fingers arises from the lateral epicondyle by a strong bundle of tendinous fibres which form part of the common tendon. The fibres forming this bundle spread out into a deep and a superficial layer, and also descend in the intervals between the common extensor and the neighbouring muscles. The fleshy fibres form a pyramidal mass arising between these extensions of the tendinous head, and as the fascia is blended with the tendinous fibres on the superficial face of the muscle it cannot be separated from the muscle for some distance below the elbow.

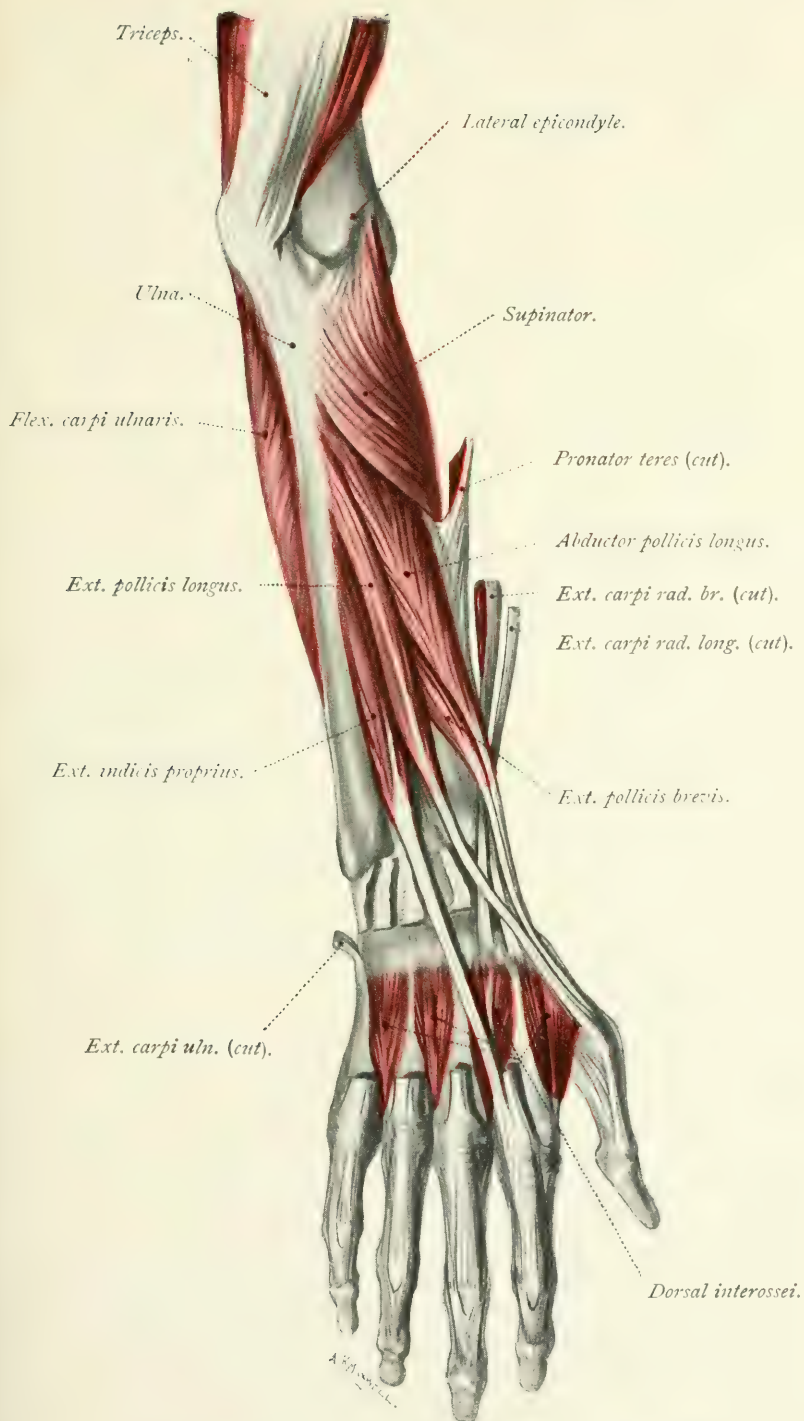


FIG. 53.—EXTENSOR MUSCLES OF FOREARM, DEEP LAYER.

The common muscular mass, becoming flattened, forms three bellies, the medial of which is divided again below, and from each part a tendon proceeds. The four tendons pass under the dorsal annular ligament, lying together with the extensor indicis proprius in the broad medial groove on the back of the radius. Descending on the back of the hand beyond the ligament, the tendons diverge from one another and go to the second, third, fourth, and fifth digits. The first and second tendons pass respectively to the index and middle fingers and are usually connected by a thin band of transverse fibres; the first is accompanied by the tendon of the extensor indicis proprius, the two becoming united opposite the metacarpo-phalangeal articulation. The third tendon runs mainly to the ring finger, but sends a slip to join the tendon of the middle finger. The fourth tendon, which is more slender, lies close to the third and divides distally into two parts, one, usually the larger, joining the ring finger tendon, the other uniting with the radial division of the tendon of the extensor minimi digiti. The marked reduction in the tendon to the little finger is correlated with the development of a special and separate extensor for this digit, the tendon of which largely replaces that of the common extensor. On the fingers the tendons have the following arrangement. Opposite the metacarpo-phalangeal joint the tendon is attached by a slip to the base of the first phalanx; here it is bound down by transverse fibres which are continued as fibrous expansions on each side round the sides of the joint, and are prolonged between the heads of the metacarpal bones to be continuous with the transverse metacarpal ligament. Beyond this the tendon enlarges into an aponeurosis on the dorsal aspect of the first phalanx and shows two wing-like expansions, one on each side; these are joined by the tendinous slips of the interosseous muscles, and on the radial side also by the tendinous insertion of a lumbrical muscle. Reaching the distal part of the first phalanx the aponeurosis divides into three slips, a central and a lateral; the central slip, which is thinner than the others, is inserted into the base of the second phalanx, while the lateral parts, continuing onwards, join together again and are inserted into the base of the terminal phalanx. A thin layer of transverse and oblique fibres bridges over the intervals between the thin portions of the aponeurosis, and binds the lateral slips to the sides of the first interphalangeal articulation.

In the case of the thumb the tendons of the two extensors lie side by side and are not inserted into an expansion. They are joined on each side by thin membranes connected with slips from the abductor pollicis brevis, first volar interosseous, and adductor obliquus pollicis muscles.

Varieties.—The varieties of the extensor digitorum communis resolve themselves chiefly into: first, the occasional deficiency of one or more of the tendons of insertion; second, and more frequently, an increase in their number: in short, there is considerable variability in the degree of longitudinal segmentation of the muscle. The increase in the number of tendons is more frequently limited to the index or middle finger alone. An additional slip to the thumb is occasionally seen. The fleshy part of the muscle may consist of four bellies, one for each chief tendon, but on the other hand there may be only two.

M. Extensor Minimi Digiti Proprius (fig. 52).—The special extensor of the little finger is closely bound up with the common extensor, of which it really forms morphologically a part. It arises from the fascial expansion over it, and from the septa between it and the common extensor and extensor carpi ulnaris. The tendon becomes free of muscular fibres above the wrist and runs in a groove between the radius and ulna in a special compartment of the dorsal annular ligament. On the back of the hand the tendon generally splits into two, the lateral division being joined by a slip from the fourth tendon of the common extensor,

and both parts end in the dorsal expansion of the little finger, in the formation of which this muscle takes much the larger share.

Varieties.—An origin from the lateral epicondyle of the humerus by means of a thin fibrous slip forming part of the common tendon is occasionally present, and more rarely there is an accessory slip from the dorsal surface of the ulna. The tendon of insertion is sometimes undivided or gives a slip to the ring finger. The ulnar slip has been observed to end on the base of the fifth metacarpal, thus exactly reproducing the arrangement of the serially homologous slip known as the *peronæus tertius* (Bryce). The muscle may be absent in rare cases, but fusion with the common extensor is not uncommon, in which case the tendon comes from the common mass.

M. Extensor Carpi Ulnaris (fig. 52).—This muscle, which is the most medial of the muscles descending on the back of the forearm, arises from the lateral epicondyle by the common tendon, from a strong intermuscular septum on its radial side, and from the fascia of the forearm. The proximal part of the muscular belly is thus surrounded by the fibrous origin; it is, as far as its middle third, closely bound down to the dorsal border of the ulna by the fascia, and it occasionally receives a few additional fibres from this portion of the bone. The tendon springs high in the forearm and is surrounded by the muscular fasciculi which are arranged upon it in a pennate fashion. It becomes free of muscular fibres a little above the wrist and runs in a special groove on the carpal end of the ulna, and through a separate compartment in the dorsal annular ligament to be inserted into the tuberosity on the base of the fifth metacarpal bone. There is sometimes a small bursa beneath the tendon.

Varieties.—The extensor carpi ulnaris, being the ulnar marginal element of the primitive extensor sheet, is represented in the leg by the two peroneal muscles. Several of the varieties observed are of interest in this connexion: thus (1) the muscle is occasionally double throughout; (2) there may be a partial attachment of the tendon to the base of the fourth metacarpal bone; (3) an independent muscle named the *ulnaris quinti digiti* has been observed arising from the lower part of the dorsal surface of the ulna and inserted into the base of the first phalanx of the little finger. This muscle may be represented by a fasciculus from the belly of the extensor carpi ulnaris, or more frequently (44 per cent.) by a dorsal slip from the tendon which may be inserted either into the metacarpal bone or first phalanx, or may join the extensor tendon of the little finger (see Extensor quinti digiti of the foot). In many cases (52 per cent.) a slip is continued from the tendon anteriorly over the *opponens minimi digiti*, to be inserted either into the fascia covering that muscle, the metacarpal bone, the capsule of the metacarpo-phalangeal articulation, or the first phalanx of the little finger. The slip is sometimes joined or replaced by a muscular fasciculus arising from, or in the neighbourhood of, the pisiform bone.

Abductor Pollicis Longus (extensor ossi metacarpi pollicis) (figs. 52, 53, 54).—This muscle, which is intimately related to the next to be described, the short extensor of the thumb, arises from a narrow oblique impression occupying the proximal part of the radial division of the dorsal surface of the ulna, below the origin of the supinator muscle, from the middle third of the dorsal surface of the radius below the insertion of the same muscle, and from the interosseous membrane between: thence descending obliquely outwards round the posterior border of the radius to its lateral surface, it ends on a tendon which appears on the deep face of the muscle and on which the fasciculi converge in a bipennate fashion. The tendon passes, in company with that of the short extensor of the thumb, in a groove on the lateral surface of the distal extremity of the radius and through a separate compartment of the dorsal annular ligament to be inserted into the base of the metacarpal bone of the thumb on its radial side. The tendon is commonly split near its insertion. One of the slips is often attached to the trapezium, and another very frequently serves as the attachment of some fibres of the abductor pollicis brevis.

Relations.—The proximal part of the muscle is concealed by the extensor communis, but at the distal end of the radius it becomes superficial, and crosses obliquely, together with the short extensor of the thumb, the tendons of the radial extensors of the carpus, conceals the insertion of the brachio-radialis, and below the extremity of the radius crosses the radial artery. A bursa intervenes between the tendons of the two muscles and the subjacent tendons of the radial extensors; there is another bursa under the tendon near its insertion which frequently communicates with the carpo-metacarpal articulation of the thumb. It is not present until after birth, and varies much in size. When extensive its lower cul-de-sac comes into close relation with the synovial sheath of the extensor carpi radialis brevis. A bursa is occasionally present between the tendon and the base of the first metacarpal bone (Whittaker).

M. Extensor Pollicis Brevis (fig. 53).—This muscle lies close to the lower border of the abductor with which it is often conjoined. Smaller than the last, it arises from the interosseous membrane and a small part of the radius about the middle third of the bone. Its tendon at first accompanies the tendon of the long abductor as above described, but separates from it on the level of the carpo-metacarpal joint of the thumb, and running along the dorsal surface of the first metacarpal bone, goes to be inserted into the base of the first phalanx.

M. Extensor Pollicis Longus (fig. 53).—Much larger than the short extensor which it overlaps, the long extensor arises from the radial division of the dorsal surface of the ulna, immediately distal to the long abductor of the thumb, and above the extensor indicis. The origin, which corresponds to about the middle third or rather more of the bone, extends on to the interosseous membrane opposite the lower part of the ulnar attachment, and some fibres also arise from the fascial septum between it and the extensor carpi ulnaris. The muscle is under cover of the extensors of the fingers and the extensor carpi ulnaris. Its tendon, which appears high up on the dorsal face of the muscle, and on to which the fasciculi converge, becomes superficial just above the wrist, and then engages in the oblique groove on the back of the distal extremity of the radius and in a special compartment in the dorsal annular ligament. Below the ligament it takes a very oblique direction, crossing the dorsal aspect of the carpus and the tendons of the radial extensors; it is then continued along the metacarpal bone and first phalanx to be inserted into the base of the terminal phalanx of the thumb.

Varieties.—The extensor muscles of the thumb are subject to considerable variation; indeed, if all the muscles be included they seem to occur as often as in one out of every six subjects dissected. The most common occur in the long abductor and consist in a more extensive cleavage of the tendon, or even of the whole muscle into separate parts. The slips into which the tendon is divided may find attachment to the annular ligament, the trapezium, the abductor brevis or opponens pollicis muscles, or the tendon may be doubly inserted into the base of the metacarpal bone. The extensor brevis, which is a muscle peculiar to man, or, more strictly speaking, is individualised to a greater degree in man, is sometimes absent, being fused, as it were, with the abductor longus, as it normally is in the Simiidae, although it may be a separate muscle even in them. On the other hand, its tendon is often united with that of the long extensor and inserted with it; or it may be continued as an independent slip to the base of the terminal phalanx. Doubling of the extensor longus is not infrequent, and the ulnar portion of the muscle may pass beneath the dorsal annular ligament with the common extensor. A slip from the tendon of the long extensor to the extensor indicis is occasionally seen. A rarer variety, representing a muscle normally existing in the dog and many other carnivores as well as in some other mammals, is the presence of an additional extensor between the indicator and the extensor pollicis longus with a double tendon and insertion into both digits. It may replace the long extensor of the thumb or the extensor indicis. In most mammals it replaces the extensor indicis, but in certain forms it co-exists with it.

M. Extensor Indicis Proprius (fig. 53).—The indicator muscle arises from the radial division of the dorsal surface of the ulna for a variable extent

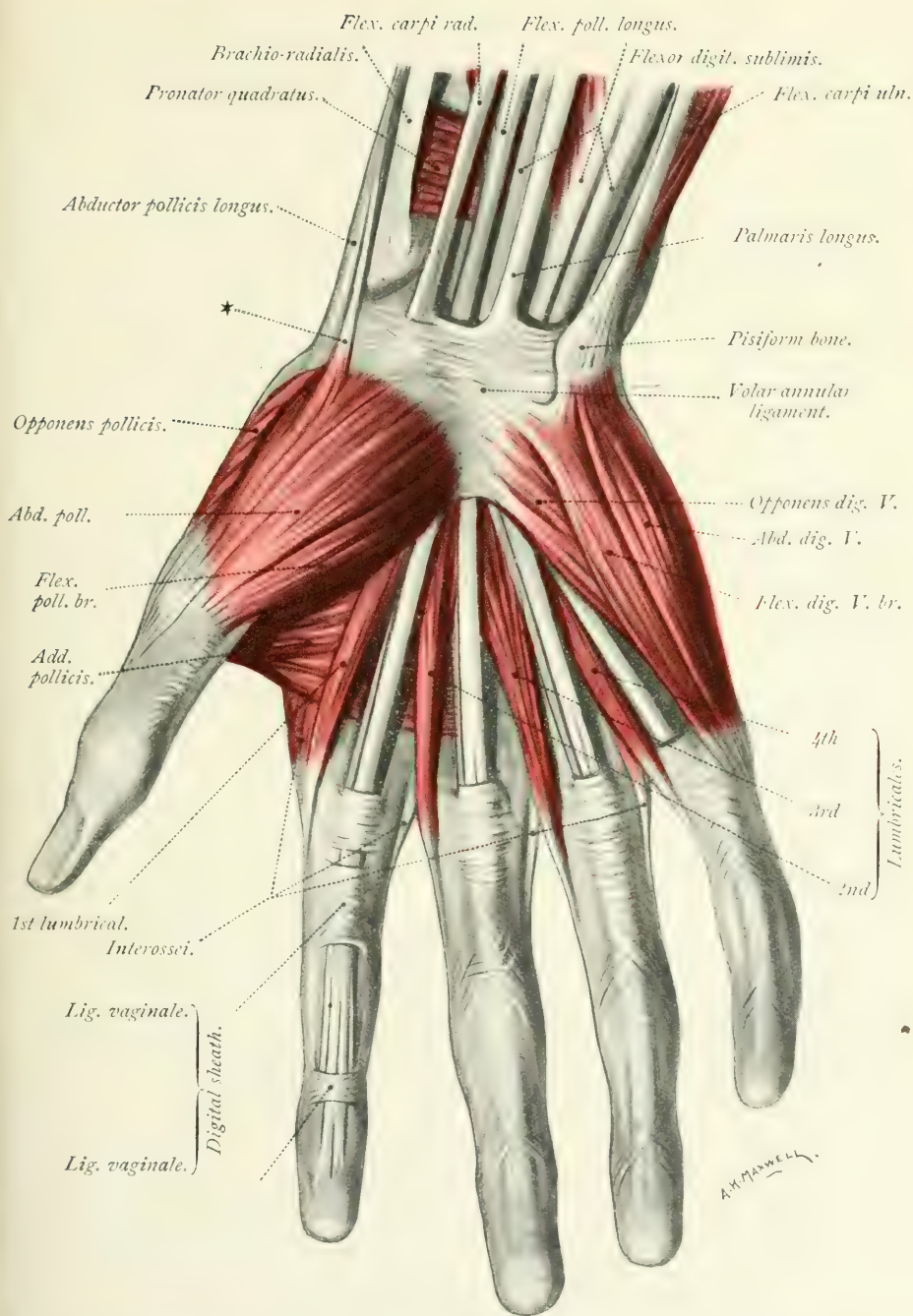


FIG. 54.—SUPERFICIAL DISSECTION OF MUSCLES OF THE PALM OF THE HAND.

★ An accessory slip frequently present connecting the long and short abductors of the thumb.

below the long extensor of the thumb, slightly from the interosseous membrane at its lower part, and from the fascial septum common to it and the extensor pollicis longus. The tendon passes with the common extensor through a compartment of the dorsal annular ligament, comes in contact with the tendon of that muscle to the index finger, and unites with it to form the expansion previously described.

Varieties.—The special muscle of the index finger is absent in rare cases. Its tendon is occasionally double and one of the slips may pass, though rarely, to the thumb or ring finger or more commonly to the middle finger. This last slip, forming an *extensor digiti III.*, may occur as a separate muscle (2.5 per cent.) arising from the ulna, or posterior ligament of the wrist-joint below the indicator. An *extensor digiti IV.* is a rarer variation. These slips of the deep or short extensor appear to be reversions to a primitive arrangement in which the muscle provides tendons to the whole series of digits. An *extensor brevis manus* is found in rare cases. It seems to appear in two forms: (a) slips arising from the back of the wrist and clearly representing slips such as just described which have descended to that position; (b) slips arising from the carpus or metacarpus and connected with the tendons of interosseous muscles, as well as the tendons of the extensor. In some cases these have been seen supplied by nerves to the interossei and therefore must be regarded as derived by delamination from them.

Nerve Supply of the Dorsal Muscles.—This group of muscles is supplied by the deep radial or interosseous branch of the musculo-spiral nerve. The nerve lies between the superficial and deep layers of muscles; the twigs of supply, therefore, enter the former on their deep and the latter mainly on their superficial aspect. The main trunk of the nerve, emerging from the supinator muscle at a point 7.5 cm. on the average, distal to the lateral epicondyle, immediately divides into a superficial and a deep branch, the latter being the direct continuation of the trunk. From the superficial part a branch is given off to the extensor digitorum communis; it then inclines medially, sends off a branch to the extensor carpi ulnaris, and is continued distally, giving off several branches to the extensor communis before finally terminating in the extensor minimi digiti. The nerve to the *extensor carpi ulnaris* enters the muscle about the junction of the proximal and middle thirds of its belly, about 8 cm. below the external epicondyle. It divides as it enters into short ascending transverse and long descending twigs which dip into the muscle substance along a vertical line of considerable extent. The *extensor digitorum communis* receives two branches, an upper which immediately enters its deep surface, and a lower which is bound up with the nerve to the extensor minimi digiti. Both these branches enter about the same level, 8 cm. or rather more below the lateral epicondyle. The nerve to the *extensor minimi digiti* is the terminal filament of the superficial division of the main nerve. It enters rather lower down, sometimes by two separate twigs about 9 cm. and 10 cm. distal from the lateral epicondyle. The fact that the nerves of the extensor communis and extensor minimi digiti are so intimately connected furnishes evidence that the latter is part of the common extensor.

The deep division of the nerve supplies the abductor pollicis longus, the extensor longus and extensor brevis pollicis, and extensor indicis. There seems from different accounts to be a considerable amount of variation in the detail of the course and subdivision of these branches. The abductor receives two twigs which supply the two parts of the bipennate belly; the nerve to the extensor brevis is bound up with a branch to the ulnar side of the abductor. The extensor pollicis longus is supplied by several twigs which enter its superficial aspect, and sometimes by twigs from the trunk of the nerve as it lies under the belly of the muscle on the interosseous membrane. The extensor indicis receives one or two twigs from the nerve as it runs down on the interosseous membrane. One of these enters the muscle on its deep surface; the other, placed higher up, enters the superficial aspect of the muscle.

Action of the Muscles of the Forearm at the Radio-Ulnar Joints and at the Wrist-Joint.—The movements at the radio-ulnar joints are pronation and supination. The muscles which effect pronation are the pronator teres and the pronator quadratus, and if the resistance to the movement is applied to the hand, as it usually is, the flexor carpi radialis and the palmaris longus also contract. The supinating muscles are the biceps and the supinator (brevis), and the extensores carpi radiales and ulnaris and the extensors of the thumb also take part when the movement is performed against resistance applied to the hand. The moments of contraction of both groups of muscles are greatest in right-angled flexion of the elbow, a position instinctively assumed when strong resistance is to be overcome.

The brachio-radialis has not been considered to be either a pronator or a supinator: it has been classified above as a pure flexor of the elbow. It is, however, usually described as being capable of effecting both movements, or at least of restoring the radius to mid-position from extreme supination (Winslow), from extreme pronation (Duchenne), and from either of these positions,

according to the amount of elbow flexion (Fick). In full extension of the elbow-joint, however, it does not seem to contract in either movement; but it comes into action at once in the slightest movement of flexion. The biceps and the pronator teres are flexors of the elbow, so that if the movements of pronation and supination are to be carried out and the elbow-joint is to remain extended, it is easily demonstrated that the triceps muscle also contracts, though to a much less extent in pronation than in supination. If flexion of the elbow occurs, the triceps at once ceases to contract. Duchenne considered, nevertheless, that the biceps could only supinate during flexion of the forearm, but though it acts more powerfully in the flexed than in the extended limb, yet even in full extension it is the most powerful of the supinating muscles. It may also be observed that when the movements of pronation and supination are extreme or are carried out against considerable resistance, the muscles of the shoulder, the abductors in pronation and the adductors in supination, are brought into action to prevent movement at the shoulder-joint. Or, as is more natural, the arm is abducted and carried backwards in supination, partly to increase as much as possible the distance between the attachments of the biceps, and partly to allow the hand to be more fully supinated by a slight rotation of the ulna at the elbow and of the humerus at the shoulder.

The movements at the wrist are (1) flexion and extension, and (2) lateral movements towards the radial and ulnar sides; and of the muscles which act only at the wrist, all of them except the palmaris longus take part in both groups of movements. The flexor muscles of the wrist are more powerful than the extensors in the proportion of 13 : 5 (Fick).

The flexor muscles are the flexor carpi ulnaris, flexor carpi radialis, and the palmaris longus, to which should be added, as pointed out by Duchenne, the abductor pollicis longus. The extensor muscles are the extensor carpi ulnaris and the extensores carpi radiales longus and brevis. In addition to these muscles, however, the flexors and extensors of the fingers and thumb take part, in fact may be the most powerfully acting muscles, in the movements at the wrist. Their part in the movements, however, is somewhat complicated, since they bring into play their normal synergists (p. 10). Those for the flexors of the fingers are the extensors of the wrist, and those for the extensors of the fingers are the flexors of the wrist. The movement of extension of the wrist, then, when the fingers are flexed to form a fist, is performed by the carpal extensors, but if during the movement the fingers be extended, the carpal extensors at once cease to contract and the extension of the wrist is carried out by the extensors of the fingers. But when the extensors of the fingers contract the flexors of the wrist also contract, and it is against their action that the extension of the wrist is carried out by the extensors of the fingers. If resistance is applied to this movement then the carpal extensors will again contract; either with the extensors of the fingers or without them if the fingers be allowed to flex, and in the former case the flexors of the wrist may or may not relax. A similar association exists between the flexors of the fingers and the extensors of the wrist, so that when the fingers are tightly flexed, as in grasping, the extensors of the wrist are contracted and the wrist is extended. If the wrist be now flexed, the grasp being maintained, there is a feeling of considerable strain due probably to the antagonistic action between the flexors and extensors, for the latter are not thrown out of action so long as the grasp is maintained. Duchenne first called attention to this association of the finger and wrist muscles, and to the peculiar results of the paralysis of one member of a pair. In lead paralysis, for example, "if the extensor digitorum communis is affected but not the extensores carpi, the effort to extend the fingers results only in flexion of the wrist" (Duchenne), but "if the fingers are flexed so as to close the fist, the wrist can be extended by the extensores carpi, though this cannot be done if the fingers are straight" (Gowers, Beevor). These combinations can be interpreted from the description given above. The nature of the association between the finger and wrist muscles was defined by Duchenne as "a moderating synergy" whereby, for example, "the extensors of the fingers would be placed in their greatest elongation, in order to augment their dynamical power . . . by the contraction of the flexors of the hand." It is more probable, however, that the muscles of the wrist should be considered as fixation muscles, for they come into action in all positions of the wrist without producing an alteration in the position, and thus allow the finger muscles to act to their fullest advantage on the fingers.

The muscles which produce lateral movement to the radial side (abduction) are the extensores carpi radiales longus and brevis, flexor carpi radialis, abductor pollicis longus, extensor pollicis longus, and the extensor proprius indicis. When the long thumb muscles contract they would produce movement of the thumb, and to prevent this the thenar muscles contract with them. The muscles which act in movement towards the ulnar side (adduction) are the extensor and the flexor carpi ulnaris. Duchenne, from electrical stimulation of the muscles, has denied that the flexors of the wrist take part in these lateral movements, but though they are not so powerful as the extensors they can be felt to contract with them in the voluntary movements.

MUSCLES AND FASCIÆ OF THE HAND

Fasciæ.—The **fascia on the dorsum of the hand** includes (1) a thin superficial layer, composed mainly of transverse fibres, continuous with the distal margin of the dorsal annular ligament, and prolonged downwards over the extensor tendons to blend with them on the fingers, and (2) a deep layer consisting of membranes stretching over the intermetacarpal spaces, being attached laterally to the bones, and covering the interossei muscles, to which they are firmly adherent. The superficial and deep lamellæ are continuous with one another between the tendons at the digital clefts. Between the two layers the tendons and their sheaths and the branches of the radial artery run. Between the tendons themselves, besides the slips already described, there extend very delicate fascial membranes, which are cleaned away in displaying the tendons and their junctional slips.

The **fascia of the palm**, like that of the dorsum of the hand, includes a superficial layer and a deep layer. The latter covers the interosseous spaces and their muscles, while the former lies immediately below the skin. The superficial layer consists (1) of a central part which is thick, strong, and tendinous in structure—from this circumstance and its relation to the tendon of the palmaris longus appropriately named the **palmar aponeurosis**—and (2) of two lateral portions which are thin, weak, and fascial in structure, and cover the eminences formed by the short muscles of the thumb and little finger.

The **palmar aponeurosis** (fig. 50, p. 119) is narrow above where it is directly continuous with the tendon of the palmaris longus, and expanded below where it is stretched across the heads of the metacarpal bones from the second to the fifth. It presents an irregular lower border owing to the fact that it is prolonged on the bases of the fingers as four processes which lose themselves on the digital sheaths. It is continuous on each side, by transverse fibres which emerge from it, with the fascia over the thenar and hypothenar eminences. Here it is also continuous with the deep fascia covering the interosseous muscles by two thin septa, one on each side. These septa divide the palm into three compartments, a *radial* containing the short muscles of the thumb and its long flexor tendon, an *ulnar* containing the short muscles of the little finger and the long flexor tendons to the little finger, and a *middle* containing the long flexor tendons to index, middle, and ring fingers.

The palmar aponeurosis consists principally of longitudinal fibres. These are derived in great part from the tendon of the palmaris longus, but there are also deeper fibres which spring from the distal border of the volar annular ligament. The longitudinal fibres spread out as they descend, but are collected in greater number over the tendons, so as to give rise to diverging bands which are continued into the processes before mentioned. The fibres which occur in the intervals between the tendons end in the overlying skin. The marginal fibres on the ulnar side spread over the hypothenar eminence, while on the radial side a broad bundle extends into the skin fold between the thumb and the index finger. The fibres of the digital bands extend on to the bases of the fingers, and there lose themselves in the fibrous tissue and skin. The skin attachments are specially close over the metacarpo-phalangeal joints, causing the depressions here between the interdigital swellings. Other fibres in the distal part of the palm turn backwards on each side of the tendons to join the deep layer of fascia and the transverse metacarpal ligament so as to form distinct secondary sheaths for each pair of tendons. The transverse fibres which complete the web of the aponeurosis are placed behind the longitudinal. They are few in number above, but well developed distally. Here they appear as a well-marked tendinous band, sometimes named the *superficial transverse metacarpal ligament*, stretching across the heads of the metacarpals. This band is composed of short fibres overarching the tendons, and longer more superficial fibres some of which extend from the radial tubercle on the head of the second to the ulnar tubercle on that of the fifth metacarpal. Distal to this band, at the roots of the fingers, other transverse fibres extend across the bases of the first phalanges in the interdigital skin folds, of which they

constitute the supports. On the fingers these fibres sweep down with the processes of the palmar aponeurosis to be attached to the digital sheaths and skin. The fibres are of varying length, and form a second and independent transverse band separately described under the name of *superficial transverse ligament of the fingers* or *palmar interdigital ligament*.

The **deep layer of fascia** covers the interosseous muscles and dips down between them to be attached to the palmar ridges of the metacarpal bones. Distally it becomes continuous with the transverse metacarpal ligament.

Digital Sheaths (fig. 54).—From the description given above it will be gathered that the tendons, as they pass through the palm of the hand, are provided with certain fibrous investments supporting the synovial sheaths. As the tendons pass on to the fingers they become surrounded with a strong fibrous sheath. Opposite the proximal and middle phalanges strong tendinous bands of transverse fibres are developed which are attached to the rough palmar margins of the phalanges and bind down the tendons firmly to the bones. These *vaginal ligaments*, as they are termed, are so rigid that when the tendons are withdrawn they do not collapse, but, with the palmar surfaces of the phalanges, form tunnels lined with synovial membrane in which the tendons glide. Over the joints the sheath remains thin and of looser texture, so that flexion is not interfered with, but it is supported by oblique bundles of fibres which decussate over the front of the joints.

Cleland described under the name of *cutaneous ligaments of the phalanges* certain bands of fibres which he observed to pass from the sides of the phalanges to the skin at the sides of the fingers. They presumably serve the purpose of retaining the skin in position during flexion of the joints.

Proximally each digital sheath is in continuity with the annular investment provided for the tendons by the fibres of the palmar aponeurosis in the distal part of the palmar hollow. The synovial sheaths of the tendons will be described later.

Muscles.—Besides the tendons of the long muscles and the lumbricals, which have already been described, there are placed in the hand one superficial muscle called the *palmaris brevis*, the short muscles of the thumb and little finger, and the interosseous muscles. Apart from the *palmaris brevis* which occupies a place of its own, the muscles of the hand have received names either from their position, the interossei, or from the assumed effect of their contraction on the movements of the fingers. Two of the muscles act directly on the metacarpal bones; the remainder, including the interossei, move the free digits.

M. Palmaris Brevis (fig. 50, p. 119).—This small and very variably developed muscle lies under the skin over the hypothenar eminence. It is thin and flat, and its fibres arising from the palmar aponeurosis and annular ligament pass transversely inwards to be inserted into the skin along the ulnar border of the hand. It is surrounded by the fatty subcutaneous tissue, crosses the muscles of the little finger, and covers the ulnar vessels and nerve. By drawing the skin of the hypothenar eminence towards the palm it supports the eminence and prevents it being flattened outwards in the palmar grip.

Muscles of the Thumb.—The short muscles of the thumb are five in number. Three of these, the abductor, opponens, and flexor brevis, constitute the thenar eminence, covering the metacarpal bone, while the two adductors lie beneath the lateral part of the hollow of the palm.

M. Abductor Pollicis Brevis (figs. 54, 55).—This muscle mainly arises from the anterior annular ligament, although a few fibres are sometimes attached to the ridge on the trapezium, or the tuberosity of the scaphoid, while an accessory

slip from the tendon of the abductor longus is frequently present (fig. 54). Proceeding downwards and outwards it is inserted by a tendon which is attached to the radial side of the base of the first phalanx of the thumb, and also gives a slip to the tendon of the extensor muscle on the dorsum of the phalanx after the fashion of an interosseous muscle.

M. Opponens Pollicis (fig. 55).—Placed beneath the abductor, and lying in the same plane with, and closely connected to the flexor brevis, the opponens arises from the anterior annular ligament along its lower border, and also from the ridge of the trapezium. It is inserted into the whole length of the metacarpal bone at the radial border, as well as the adjoining part of the palmar surface. The opponens is to be regarded as a portion of the short flexor with which it is generally more or less intimately united.

M. Flexor Pollicis Brevis (figs. 54, 55).—The short flexor of the thumb is intimately united, as mentioned above, with the opponens along its radial border, and is placed on the radial side of the long flexor tendon. It arises principally from the radial two-thirds of the anterior annular ligament, but some fibres may be attached to the ridge on the trapezium. It descends along the long flexor tendon to be inserted into the radial side of the first phalanx of the thumb, and a sesamoid bone is developed in it over the lateral facet on the head of the metacarpal bone.

M. Adductor Pollicis (fig. 55).—This muscle consists of two portions named respectively the **adductor transversus** and the **adductor obliquus**. These two are united at their insertion, but are separated at their origins by a space through which the palmar branch of the radial artery enters the palm. The *adductor transversus* arises from the ridge on the distal two-thirds of the shaft of the third metacarpal bone. The *adductor obliquus* arises in several slips from the proximal ends of the second and third metacarpal bones; from the trapezoid and capitate bones and volar carpal ligaments; and from the sheath of the flexor carpi radialis as well as the deep fascia over the third, and sometimes the fourth, interosseous spaces. It passes obliquely downwards to be inserted with the transverse adductor into the medial side of the base of the first phalanx of the thumb. A sesamoid bone is developed in the tendon over the medial facet on the head of the metacarpal bone. The most proximal bundles usually form a considerable fasciculus which inclines radialwards behind the long flexor tendon to join the flexor brevis and the outer sesamoid bone. This is frequently described as the deep head of the flexor pollicis brevis, but from the morphological point of view it is undoubtedly part of the adductor.

Muscles of the Little Finger.—In this group are included three short muscles passing to the little finger—the abductor, flexor brevis, and opponens minimi digiti. They form the *hypothenar eminence*.

M. Abductor Minimi Digiti (figs. 54, 55).—This muscle arises chiefly from the lower border and medial surface of the pisiform bone, and the ligaments between it and the hamate bone, and is inserted into the base of the first phalanx of the little finger on its ulnar side, a slip being sent to the extensor tendon as in the case of the abductor pollicis brevis.

M. Flexor Brevis Minimi Digiti (figs. 54, 55).—Separated from the abductor muscle by a small interval through which the deep palmar branches of the ulnar artery and nerve pass, the short flexor arises from the hamulus of the hamate bone and the volar annular ligament. It is inserted with the abductor into the ulnar side of the base of the first phalanx of the little finger. The muscle is sometimes absent, or becomes incorporated with the abductor from which it is always a little difficult to separate.

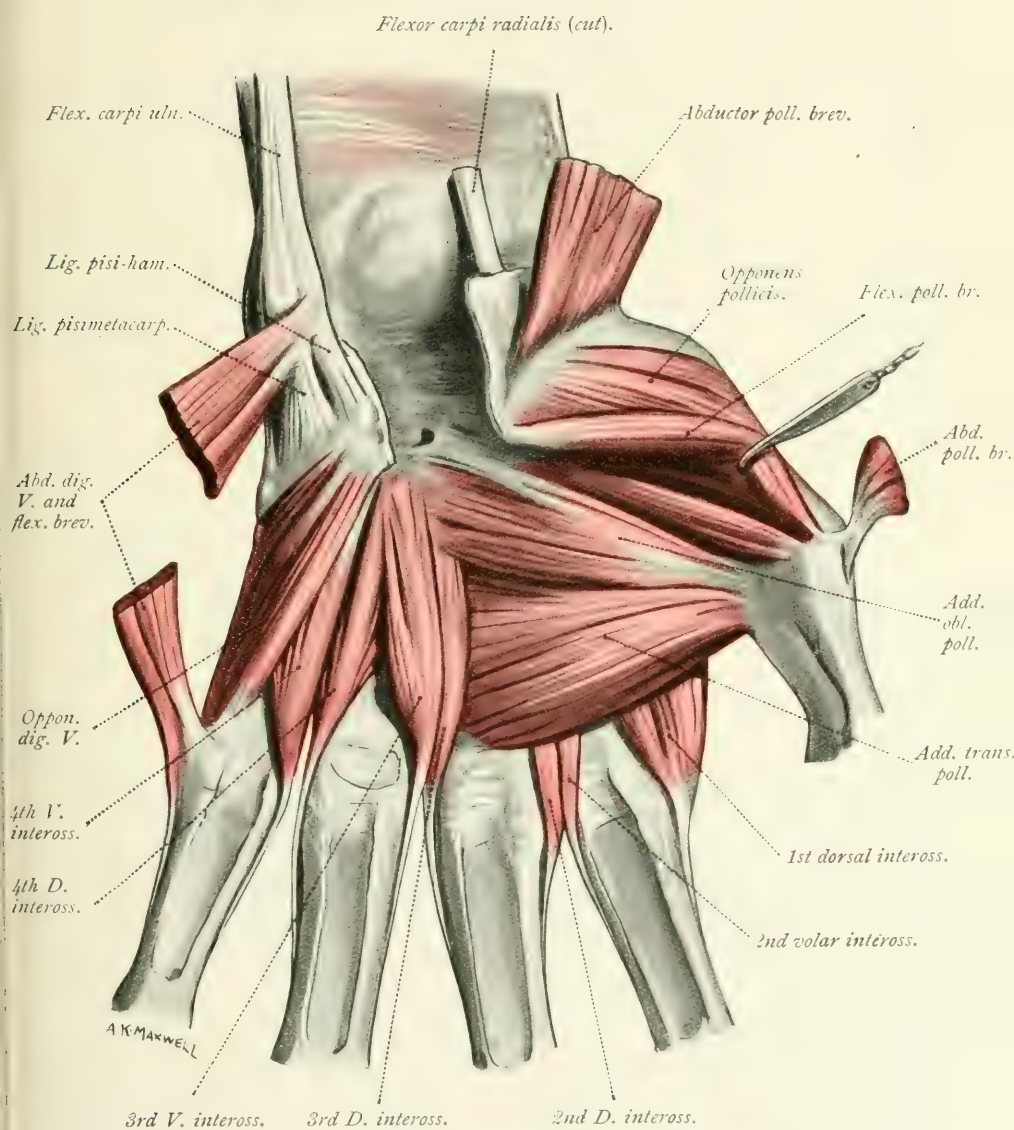


FIG. 55.—DEEP MUSCLES OF THE PALM OF THE HAND.

M. Opponens Minimi Digiti (figs. 54, 55). The opponens muscle lies under the flexor brevis, but separated from it by a layer of loose fascia. It arises from the volar annular ligament and the hook of the hamate bone, and is inserted into the ulnar side of the shaft of the fifth metacarpal bone along its whole length. It is frequently divided into two lamellæ by a cleft through which the deep branches of the ulnar artery and nerve pass.

MM. Interossei (figs. 55, 56, 57).—This series of muscular slips receives their name from their position between the metacarpal bones. This position is a secondary one, for at their first appearance the rudiments of the muscles occupy a position volar to the metacarpals. They are divided into two sets, four dorsal and four volar, the latter being seen only from the palmar aspect, while the former are seen best from the dorsal aspect of the metacarpus.

All the interossei muscles have certain features in common. They arise from the metacarpal bones and are inserted, each into the base of the first phalanx of the finger on which it operates, by a tendon which sends a tendinous expansion to the extensor tendon on the dorsum of the finger. In virtue of these attachments the interossei muscles flex the first phalanges on the metacarpal bones, and at the same time by pulling on the extensor tendons they extend the two distal phalanges. This curious action will be considered more in detail later on. The attachments to the phalanges are, however, so arranged, that certain of the interossei produce abduction of the digits from a line passing through the middle finger, while others of them adduct the fingers to that line. It is found that the dorsal interossei are abductors and the palmar are adductors, and if this point be kept in mind the attachments of the slips are easily understood and remembered.

The **dorsal interossei muscles** (fig. 56) occupy the spaces between the metacarpal bones and are numbered I., II., III., and IV., from the radial side. Each muscle arises from both the bones between which it lies, but most extensively from that which supports the finger upon which it acts. The muscle fibres are attached to the dorsal parts of the lateral faces of the metacarpal bones and converge pennately on a central tendon; the tendon becomes free of muscular fibres at the level of the metacarpo-phalangeal joint, and giving a slip to the base of the phalanx it ends in the expansion above mentioned. The proximal fibres of this expansion pass over the extensor tendon and decussate with those of the opposite side. The middle fibres join the lateral borders of the tendon and go to the base of the second phalanx, while the distal fibres, joined by those of the related lumbrical muscle, pass with the extensor tendon to the base of the third phalanx. The second and third muscles are inserted into the middle finger and draw it to either side; the first is attached to the radial side of the index finger; the fourth to the ulnar side of the ring finger. They draw their fingers away from the middle line of the hand. The first dorsal interosseous muscle, sometimes named the abductor indicis, is larger than the others. The radial and larger head of origin arises from the proximal half of the ulnar border of the first metacarpal; the ulnar head is attached to the whole length of the radial side of the second metacarpal bone, and between these heads there is a wider proximal gap than in the case of the other members of the series. In connexion with this muscle a slip may be found arising from the base of the second metacarpal bone, from the tendon of the flexor carpi radialis and from the ligaments in connexion with the trapezoid bone, and inserted into the radial sesamoid. It constitutes a *flexor brevis indicis* (Wood Jones). Through the interval between the heads of the first dorsal interosseous muscle the radial artery passes forward into the palm of the hand. Through the corresponding intervals in the remaining interossei muscles small perforating arterial branches are transmitted.

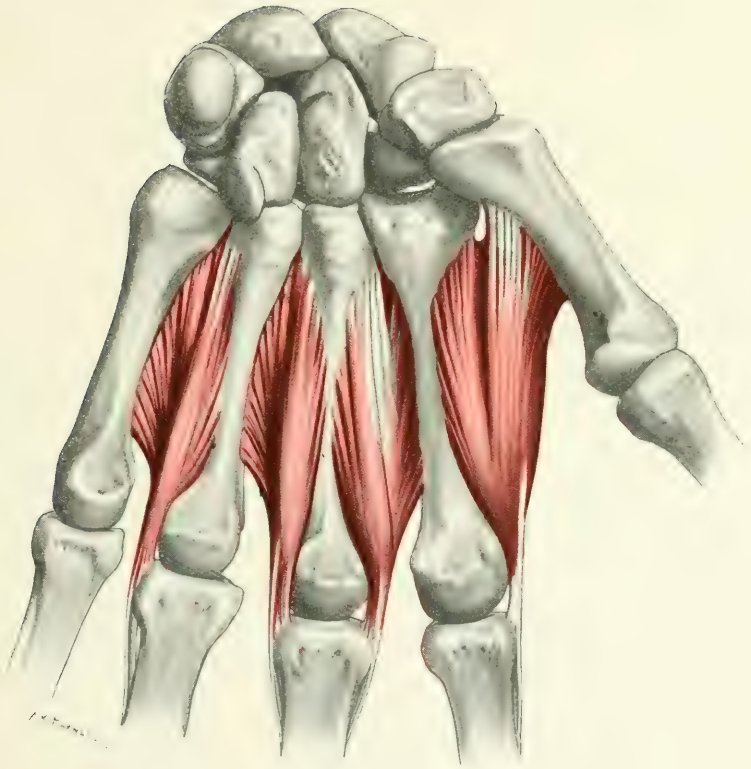


FIG. 56.—THE FOUR DORSAL INTEROSSEI MUSCLES.

The **palmar interossei muscles** are visible only from the palmar aspect of the hand (fig. 57). They are likewise four in number, one in each intermetacarpal space. Each muscle arises from the metacarpal bone of the digit on which it acts. The muscular fibres converge on a tendon which, becoming free of these a little above the level of the metacarpo-phalangeal joint, is inserted partly into the base of the first phalanx and partly into the extensor tendon. The first palmar interosseous muscle is a slender fasciculus which arises from the ulnar side of the base of the first metacarpal bone, but sometimes extends to the base of the second, or receives fibres from a fibrous arch bounding the gap for the radial artery in the first dorsal interosseous muscle. It is inserted into the medial side of the base of the first phalanx of the thumb in intimate connexion with the tendon of the adductor pollicis and gives a slip to the extensor tendon on the dorsum of that phalanx.

The second muscle is attached to the ulnar side of the index finger, the third and fourth to the radial sides of the ring and little fingers respectively. Thus all are arranged to draw the digits to which they are attached towards the middle finger, which is itself unprovided with special adductors, since the two dorsal interossei muscles attached to it will necessarily act alternately as adductors or abductors.

Small bursæ are generally present between the tendons of the interossei muscles and the metacarpo-phalangeal articulations, as well as in the interspaces between the heads of the four inner metacarpal bones.

Varieties and Morphology of the Short Muscles of the Hand.—The *palmaris brevis* is rarely absent, but varies greatly in the strength of its muscular fibres, and somewhat also in their length and direction. It is sometimes found running into the flexor brevis minimi digiti. The *abductor pollicis* is often divided into an outer and an inner part, or it may receive slips from the navicular bone or styloid process of the radius. Its absence has been noted. An accessory slip is very frequently found joining the muscle with the long abductor (fig. 54). Accessory slips also occur but more rarely, connecting the short abductor with the palmaris longus, extensor carpi radialis longus (or accessory extensor carpi radialis), the opponens, or flexor pollicis brevis. A cutaneous slip is frequently present attached to the skin over the proximal part of the thenar eminence, and inserted below on the radial side of the first phalanx.

The *opponens* is sometimes divided into two portions, and in a few instances its absence has been noted. The absence of the *short flexor* has also been observed, or it may be incorporated with the opponens. The belly may be divided. The *adductor* is a triangular muscle and it shows a tendency special to this class of muscle to be split into radial parts. The subdivision into the two main portions is probably to be explained in this way, not on morphological grounds. The relative extent of the two parts and the closeness of their connexion are subject to variation. Occasionally fasciculi are seen arising from the palmar metacarpo-phalangeal ligaments, forming a *transversus manus*.

The *abductor minimi digiti* is occasionally divided into two or even three slips. In other cases it is united with the flexor brevis. Its absence has been observed. An accessory head is not infrequently present arising from the tendon of the flexor carpi ulnaris, or from the volar annular ligament, the palmaris longus, the fascia of the forearm, or even the ulna. In some cases the additional head arises a considerable distance above the wrist from the intermuscular fascia under either the flexor carpi ulnaris or flexor carpi radialis. Passing downwards it covers the ulnar artery to a greater or less extent, and ends in the abductor or flexor brevis minimi digiti. A portion of the muscle is occasionally inserted into the metacarpal bone, or volar ligament of the metacarpo-phalangeal joint (Le Double). A small separate slip may extend from the pisiform bone to the metacarpal bone (Quain, 10th Edition), constituting a *pisiformis* muscle. The *pisiformis* is a small muscle first described by Calori, and noted by Gruber as occurring in 2.5 per cent. of hands, extending between the pisiform bone and the hook of the hamate bone. A similar slip may extend from the pisiform to the anterior annular ligament. The *flexor brevis minimi digiti* is frequently united with the abductor, sometimes with the opponens. Its absence has been observed, as has also that of the opponens.

The *interossei muscles* are occasionally double in one or more spaces, or they may be absent in one or more spaces. The condition normal in the foot, and peculiar to man, has been observed,

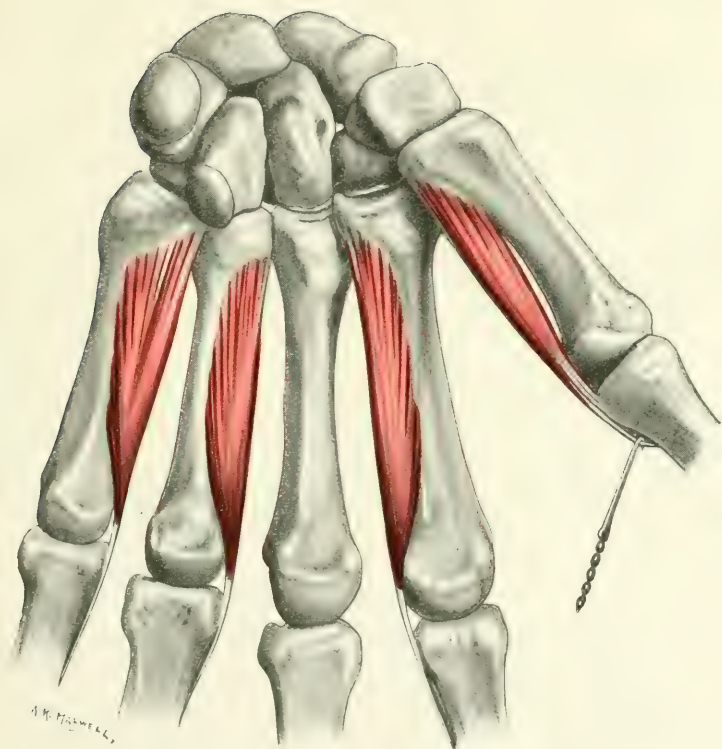


FIG. 57.—THE FOUR VOLAR INTEROSSEI MUSCLES.

viz. the insertion of the second dorsal interosseous muscle to the ulnar side of the index, and of the second palmar interosseous muscle to the radial side of the third finger, so that the index becomes the axis and not the medius.

The variations of the marginal muscles, *i.e.* the abductors, the short flexors, the opponens pollicis, and the opponens minimi digiti, are of importance in connexion with the morphology of the hand muscles and are all derivatives of the superficial palmar flexors (p. 28). In human development they arise from premuscle masses which are independent of one another and of the rudiment of the interossei. These developmental data serve to support the view that the marginal muscles belong to a superficial stratum, as M'Murich first pointed out, and not to the series of short deep flexors. They are all derived, except a portion of the opponens minimi digiti which must be referred to the deep layer, from the superficial palmar mass which centrally gives origin to the superficial short flexors of the digits. These last, as explained on p. 29, have become entirely tendinous, and are represented by the perforated tendons of the flexor digitorum sublinis. Cases have been described¹ in which fleshy slips are attached to one or more of these tendons in the palm of the hand, and may readily be explained as due to

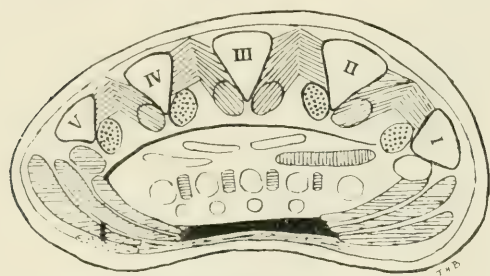


FIG. 58.—SCHEME TO SHOW THE DERIVATION OF THE MUSCLES OF THE HAND FROM THE IDEAL GROUND PLAN FIGURED ON PAGE 29.

The palmar aponeurosis is represented by a thick black line; the superficial short flexor slips to the digits are represented by the perforated tendons; the thenar marginal mass yields the abductor, the opponens, and the flexor brevis pollicis; the hypothenar mass the palmaris brevis, the abductor, the flexor brevis, and part of the opponens digiti V; only one of the four adductors is retained; the deep short bicipital flexors give the interossei, the palmar arc stippled, the dorsal cross-hatched; the ulnar member of the fourth pair forms part of the opponens digiti V; the radial of the first pair either disappears or is conjoined with the short flexor of the thumb; the intermetacarpal fibres are merged with the heads of the short flexors to form the dorsal interossei which thus arise from two bones.

to form the four abductors. The intermetacarpal fibres probably arise in mammals by delamination from the interossei. M'Murich referred them to a separate layer of muscles which he described in lower tetrapodal vertebrates. A glance at the diagram will make clearer than any description the views here adopted on the morphology of the short muscles of the hand.

Innervation of the Intrinsic Muscles of the Hand.—The median nerve supplies the abductor pollicis brevis, the opponens, and the flexor brevis by a common trunk which arises immediately below the volar annular ligament. The branch to the abductor enters the muscle on its deep surface near its ulnar border, while the main branch is continued under the abductor, and after supplying some twigs to the flexor brevis, terminates in a number of filaments to the opponens. The distal part of the superficial portion of the flexor brevis sometimes receives twigs from the lateral branch of the median which becomes the proper digital nerve of the thumb. The nerve of supply to the part of the adductor which is generally described as the deep head of the flexor brevis (see above) is doubtful. It receives certainly in most cases a twig from the ulnar nerve, but, as Froshe and Fränkel show, there is at this point a free communication between median and

reappearance of the fleshy fibres of short flexors. If the figure of the ideal hand (p. 29) be compared with fig. 58 it will be seen that of the adductors only that of the thumb survives; those of the other digits have disappeared. The adductor of the thumb has undergone great expansion in the human hand; it has spread to the carpus proximally, and distally to the head of the metacarpal; further, slips may be added which arise from the transverse metacarpal ligament; it has also become to some degree merged with the flexor brevis of the thumb, making it difficult to distinguish between the two muscles. The fate of the short deep flexors, of which there were originally two to each digit, one radial, one ulnar, is as follows (fig. 58): the radial slip of the thumb seems to disappear, or to be taken into the flexor brevis; the ulnar slip of the little finger becomes part of the opponens. The rest give origin to the interossei muscles. Four remain separate, viz. the ulnar heads of I. and II. and the radial of IV. and V. as the four palmar interossei. The dorsal interossei arise thus: the radial muscle of II., both radial and ulnar of III., and the ulnar of IV. are combined with the intermetacarpal fibres

¹ Congdon, E. D., *Anat. Record*, vol. xix.

ulnar nerves, and it is impossible to determine anatomically from which the motor twigs come. The fact that flexion of the first phalanx can be obtained by faradic stimulation in cases of median paralysis, when the abductor and opponens do not react, points to its supply by the ulnar nerve and also indicates that this part of the adductor may have a flexing action and is physiologically a part of the flexor brevis. The ulnar nerve supplies the palmaris brevis by twigs given off from its superficial branch, and the abductor and flexor brevis and opponens by its deep branch. All the interossei muscles receive twigs from the deep branch. When this reaches the cleft between the transverse and oblique parts of the adductor of the thumb it gives two branches, one to each division of the muscle. The branch to the oblique adductor pierces the muscle, and gives a terminal branch to the first volar interosseous muscle. The median and ulnar nerves establish connexions, as already mentioned, between the bases of the first and second metacarpal bones, and the source of the motor fibres to the deep muscular slips cannot be determined with absolute certainty; indeed it seems, from accounts given by various observers, to vary.

Action of the Muscles of the Hand

(a) *Muscles which Act on the Fingers.*—The movements of the fingers are (1) flexion and extension of the individual phalanges; and (2) lateral movements, abduction and adduction, of the fingers as a whole at the metacarpo-phalangeal joints.

The flexor muscles of the fingers, which are far more powerful than the extensors, are the flexor digitorum sublimis, the flexor digitorum profundus, and the interossei with the lumbricals as associates; and each of these muscles is, in the normal movement, specialised in its action on one joint. The distal phalanges are flexed by the flexor profundus and the middle phalanges by the flexor sublimis, and normally these muscles have no other action even though in most people these phalanges cannot be separately flexed. The flexor profundus, however, can act on the middle phalanges, and does so if the flexor sublimis is paralysed, but only after the distal phalanges are fully flexed. The two terminal phalanges can be fully flexed without flexion of the basal phalanges, the extensor digitorum communis being brought into action to fix the metacarpo-phalangeal joints. The proximal phalanges are flexed on the metacarpal bones by the interossei and the lumbricals (Fallopian, 1561), and the long flexors of the fingers may also act, though only after they have fully flexed their proper joints. Duchenne, however, denies that the long flexors have any action on the metacarpo-phalangeal joints, and this would almost seem to be borne out in cases of paralysis of the proper flexors. The metacarpo-phalangeal joint of the little finger is also flexed by the flexor brevis and the abductor digiti minimi. Flexion of all the phalanges against resistance, as in tightly grasping an object, brings into action the radial and ulnar extensors of the wrist (*v. post*).

The extensors of the fingers are the extensor digitorum communis and the proper extensors of the little and index fingers, and the interossei and the lumbricals which are inserted into their tendons. The interossei and the lumbricals¹ are extensors of the second and third phalanges, and the abductor minimi digiti has a similar action in the little finger. The action of the interossei and lumbricals muscles, therefore, is to flex the proximal phalanges and to extend the two distal phalanges, and this combination of movements cannot be carried out when they are paralysed. The proximal phalanges are extended by the extensor communis and its associates of the little and index fingers. Duchenne has stated that this is the sole action of these muscles, that is, that they do not act as extensors of the two distal phalanges. This seems to be borne out in cases in which the interossei and lumbricals are paralysed and the extensor communis is intact ("claw hand"), for there is then inability to extend the two distal phalanges. It has been further pointed out, however, in these cases, that if the proximal phalanges be kept passively flexed on the metacarpal bones the distal phalanges may be extended by the extensor communis. The inability to extend the two distal phalanges in "claw hand" is therefore probably due to "insufficiency" of the extensor communis² through over-extension of the proximal phalanges, which is not prevented by the paralysed interossei and lumbricals. The extension of the proximal phalanges, as Duchenne pointed out, is accompanied by contraction of the flexors of the wrist, namely, the flexores carpi radiales and ulnaris and the palmaris longus. The extensors of the wrist will also contract if the movement is made quickly or against resistance.

The lateral movements of the fingers are abduction away from and adduction towards the

¹ Poore (*Lancet*, 1881) attributes to the lumbricals the function of relaxing the flexor tendons while effecting extension of the two distal phalanges.

² The length of the contraction of the extensor digitorum communis is relatively very short.

line of the middle finger, which can itself be abducted in two directions. The movements are most free when the fingers are extended. Adduction is performed by the palmar interossei and abduction, except of the little finger, by the dorsal interossei. The lumbricals seem to take no part in either movement. Abduction of the little finger is effected by the abductor minimi digiti and to some extent by the extensor proprius; and as the former muscle arises from the pisiform bone and would displace it when it contracts, the flexor carpi ulnaris contracts with it to fix the bone in position. Further, to obviate the action of the flexor carpi ulnaris on the wrist, the abductor pollicis longus also contracts unless the hand be first adducted to the ulnar side.

It should be noted that a spreading out of the fingers takes place when they are extended (and that they are closed together again when flexed), but this abduction (or adduction) action of the long extensors (or flexors) should be distinguished from that of the interossei and cannot be produced while the fingers are held in one plane.

(b) *Muscles which Act on the Thumb*.—The natural movements of the phalanges of the thumb are simple flexion and extension, in which the palmar surface of the thumb remains more or less at right angles to the palm of the hand. There is little, if any, voluntary lateral movement at the metacarpo-phalangeal joint.

Flexion of the terminal phalanx is effected by the flexor pollicis longus, which, like the flexor profundus of the other digits, acts normally only on the distal joint. It can, however, flex the proximal phalanx and even the metacarpal bone after the distal phalanx is fully flexed, so that if the terminal phalanx alone is to be flexed, the extensor brevis and the abductor pollicis longus contract to fix the other joints of the thumb; and since these muscles can produce abduction of the wrist the extensor, and later the flexor, carpi ulnaris also contract. This wide combination of muscles involved in a simple movement is an excellent example of synergic action of seemingly unrelated muscle groups. Extension of the terminal phalanx is performed by the extensor pollicis longus, and, according to Duchenne, the flexor brevis and abductor pollicis brevis can also so act, since they send dorsal expansions to the long extensor tendon. According to Wood Jones, however, if the long extensor be paralysed, only a very feeble extension of the distal phalanx is possible and in most cases is a passive extension brought about by the active flexion of the proximal phalanx.

Flexion of the proximal phalanx can be performed by the whole series of short muscles which are inserted into the radial and ulnar margins of its base; namely, the abductor brevis, flexor brevis (both heads), first palmar interosseous (*cf.* p. 154), and the adductor pollicis (both parts). Extension of this phalanx is carried out by the extensor pollicis brevis and in a lesser degree the extensor pollicis longus may also act.

The primary movements of the metacarpal bone are so continuously graduated into one another that it is difficult to define the precise movement which is included in any one term. There are therefore very varying descriptions of the actions of the thumb muscles. *First*: As regards rotation round a longitudinal axis, this does not occur as an isolated, nor can it be induced as a voluntary, movement, but in the movement called *opposition* of the thumb the metacarpal bone undergoes a longitudinal rotation in a medial direction through the action of the opponens pollicis. The opposite rotation, by which the thumb-nail comes to face directly backwards, is produced by the extensor pollicis longus; although the adductor pollicis has been described as producing this movement it is possible in its paresis. *Second*: Abduction and adduction are movements through a dorso-volar axis, and though not completed in one plane are conveniently described as taking place in a plane at right angles to the palm of the hand. It is difficult to perform these movements without an accompanying rotation of the thumb towards the palm in abduction, and away from it in adduction. The abductor muscles are the abductor brevis, flexor brevis (both heads), opponens pollicis, the abductor longus, and the extensor pollicis brevis. Duchenne would omit the abductor longus from this group, and he ascribes to it solely an opposing action; there is little doubt, however, but that the muscle can be felt to contract in the movement of abduction as described above. But, as has been pointed out by Wood Jones, this muscle can pull the metacarpal bone of the thumb and trapezius in a palmar direction, and this action combined with the contraction of the adductor pollicis may produce a movement which simulates true opposition of the thumb, and this even in the absence of the opposing muscles. Adduction of the thumb is performed by the adductor pollicis (both parts), the first palmar interosseous, the extensor longus (Duchenne), and possibly to a very slight extent by the first dorsal interosseous muscle. Since the long extensors and abductor of the thumb can produce movement at the wrist, the flexor carpi ulnaris contracts during abduction and adduction of the thumb. *Third*: Flexion and extension of the metacarpal bone—that is movement in a plane parallel to the palm of the hand—are seldom performed alone. The flexion movement, indeed, is considerably limited and is awkward to perform; and it is to be distinguished from opposition of the thumb by the absence of rotation and adduction. The flexor muscle of the metacarpal is the opponens pollicis, but the flexors of both phalanges will also act if the phalanges be flexed.

Extension¹ is performed by the extensor longus and abductor pollicis longus, and is accompanied by contraction of the extensor and flexor carpi ulnaris in all positions of the wrist.

Opposition of the thumb is a complex movement which is initiated best from the position of abduction. Full abduction, as already indicated, is accompanied normally by longitudinal rotation, so that the surface of the thumb comes to face the palm of the hand. From this position the thumb is carried forwards to meet the other fingers by a movement which involves flexion, adduction, and further longitudinal rotation. Movement in the opposite direction has been termed *reposition*. The muscles which take part in opposition are the abductor pollicis brevis, opponens pollicis, flexor pollicis brevis, first palmar interosseous,² adductor pollicis; and to some extent at the beginning of the movement the abductor pollicis longus. In the absence of the thenar muscles it is only a "trick" opposition which can be performed.

Synovial Sheaths of the Hand.—These will be dealt with in this section separately, both for convenience of description and on account of their practical importance.

Sheaths for Extensor Tendons.—As already stated, under the head of the posterior annular ligament of the wrist there are six separate compartments beneath this structure conveying the tendons from the forearm to the hand, and each of these compartments is lined with a single synovial sheath. In the foetus each tendon has its own investment, but the septa between the tendons, in the case of certain associated tendons, disappear in the course of development, so that the number of separate sheaths becomes reduced. One or other of the intervening septa may, however, remain, in which case instead of there being a sheath common to the tendons within a compartment, each tendon is provided with its own sheath. Sometimes a tendon may glide quite free in its sheath. In other cases there may be a complete tendon "mesentery," or this may be reduced to detached proximal and distal folds.

The individual synovial sheaths will be described in the same order as the compartments were enumerated in the description of the dorsal annular ligament.

I. Abductor Pollicis Longus and Extensor Pollicis Brevis.—The sheaths of these tendons, primitively separate, communicate freely in the middle, but remain separate both proximally and distally. The synovial investment begins on each tendon just below the point where it crosses the tendons of the radial extensors of the wrist, and is continued downward to the carpo-metacarpal joint of the thumb in the case of the short extensor, and to about a centimetre above its insertion in the case of the long abductor. Occasionally the two sheaths remain distinct along the whole length of the tendons.

II. Extensores Carpi Radialis Longus et Brevis.—These tendons are provided with separate sheaths in the infant, but in the adult the dividing septum is absorbed posteriorly so that the sheaths communicate freely immediately under the ligament; anteriorly, *i.e.* next the bone, the partition persists and separates the common sheath into two compartments. The sheath begins below the point where the tendons are crossed by the short extensor of the thumb, and are continued to the distance of about a centimetre from their insertions. At the point where the extensor pollicis longus crosses the tendons there is a free communication between the synovial sheath of that muscle and the sheath of the short radial extensor.

III. Extensor Pollicis Longus.—The sheath of the tendon extends some considerable distance above the annular ligament and includes the lowest fleshy fibres of the belly of the muscle. It extends distalwards on the tendon to the

¹ If the hand be laid flat on a table and the thumb outstretched it is then in the position of full extension.

² It is to be remembered that this muscle is innervated by the ulnar nerve.

level of the upper border of the trapezium, but may extend still further by establishing a communication with a separate sheath or bursa, which is placed around the tendon, or between it and the proximal end of the first metacarpal bone (bursa vaginalis inferior of Monro). It communicates, as just mentioned, with the sheath of the extensor carpi radialis brevis.

IV. Extensor Digitorum Communis and Extensor Indicis.—There is a common sheath for these tendons. It is the largest of the series but is shorter than the others. It is single above where it rises to the proximal border of the annular ligament, but distally it gives off three processes which extend on the tendons some distance below the ligament. The first cul-de-sac surrounds the tendons proceeding to the index finger, the second invests the tendon to the middle finger, and the third, the longest of the three, is continued on the tendon to the ring and little fingers.

V. Extensor Minimi Digiti.—The synovial sheath for the tendon of this muscle is a lengthy one. It begins on the level of the proximal border of the ligament but descends nearly to the middle of the fourth intermetacarpal space, where it divides into two processes, one for each division of the tendon. The tendon is sometimes free, but there is generally a large meso-tendon along its radial border.

VI. Extensor Carpi Ulnaris.—The sheath of this tendon begins a short distance above the annular ligament, and descends to a point just short of its insertion. There is generally a mesentery-like fold along the whole length of the tendon on its radial border. The sheath is wider, therefore, and rises higher, on the ulnar side.

It will be recollected that under the description of the individual muscles various bursæ which intervene between the tendons and the bones at their insertions were mentioned, viz. (1) a bursa under the tendon of the abductor pollicis longus; (2) an occasional bursa between the tendon of the extensor carpi radialis longus and the base of the second metacarpal; (3) a constant or frequent bursa between the tendon of the extensor carpi radialis brevis and the styloid process of the third metacarpal bone. Other bursæ may also exist: (*a*) between the tendon of the index finger and the proximal extremity of the second metacarpal and tendinous insertion of the extensor carpi radialis longus; (*b*) between the tendon of the ring finger and proximal end of the fourth metacarpal bone; (*c*) between the extensor tendons and heads of the metacarpals; (*d*) small subcutaneous bursæ over the knuckles or over the first interphalangeal joints.

Synovial Sheaths of the Flexor Tendons.—Two groups of synovial sheaths are described, digital and palmar. There are two main palmar sacs, one connected with the tendon of the flexor pollicis longus, and a second, much larger, related to the superficial and deep flexor tendons. These are at first separate from the series of digital sheaths which invest the tendons as they lie in the flexor sheaths. But subsequently, in the majority of hands, the digital synovial sheath of the thumb and that of the little finger join the radial and ulnar sacs in the palm respectively. The sheaths connected with the tendons of the middle and ring fingers have never been seen connected with the palmar sac, but in a unique instance described by Froshe there was a connexion in the case of the sheath of the index finger tendons. The fact that the first lumbrical muscle was absent in that instance, suggests that the presence of the lumbrical muscles in the palm may determine the condition generally met with. The communication between digital and palmar sheaths is practically constant in the case of the thumb, but in the fifth finger they frequently remain unconnected.

The synovial investments of the tendons in the digital sheaths extend down to the bases of the ungual phalanges, just beyond the lowest of the transverse creases on the fingers. Proximally they rise to a higher level than the heads

of the metacarpal bones, reaching the level of the lower palmar cutaneous furrow. In the fingers where two tendons are present each has a separate investment of the "visceral" layer. There is no continuous meso-tendon, but there are certain synovial bands known as *vincula tendinum* which attach the tendons to one another and to the posterior wall of the sheath. There are two sets of these *vincula brevia* and *vincula longa*. The former are membranous bands, and are two in number in each sheath: a distal, triangular in shape, continuous with the under side of the tendon of the flexor profundus at its insertion; and a proximal, quadrilateral in form, which passes from a synovial band, here connecting the superficial and deep tendons, to the back of the sheath on the first phalanx. The ligamenta longa are slender, somewhat rounded bands or threads, variable in number, but belonging to two categories, medial and lateral. The former comprise bands joining the superficial and deep tendons, the latter pass from the superficial flexor to the back of the sheath on either side. The main end served by the vincula is the supply of blood vessels to the tendons. But to some extent they help to bind the tendons to the bones. In the *vincula brevia* to the deep flexor tendons slight bands of yellow elastic tissue extend from the tendons to the heads of the second phalanges; they are comparable to the elastic ligament found in the same position in ungulates. They may, though this seems doubtful, assist in drawing down the tendons after flexion of the fingers (Marshall, 1853).

The interruption of the meso-tendons and certain displacements of the vincula are to be explained by the free movements of the tendons in their sheaths. These also explain the manner in which the parietal layer is reflected on to the tendons at the proximal ends of the thecæ (see p. 17). The parietal layer before it passes on to the tendons is carried backwards along them for a certain distance, and folded upon itself. The free margin of this fold is transverse behind, but in front is prolonged further down and brought to a point on the anterior surface of the superficial flexor tendon. The cul-de-sac between fold and tendons is deeper behind and becomes progressively shallower towards the front, so that by comparison with the frenum of the prepuce Poirier names the reflected fold *guine prepupiale*.

The main palmar sheaths, as already stated, are two in number, radial and ulnar. They are separated by a longitudinal septum enclosing the median nerve. The *radial sac* is continued proximally on the tendon of the long flexor of the thumb, under the volar annular ligament, and extends for a short distance above its proximal border. The tendon has commonly a wide meso-tendon, continuous or interrupted, in the thenar part of its course.

The *ulnar sac* is much larger than the radial. It is most extensive on the ulnar side, and communicates generally with the digital synovial sheath of the little finger. It extends proximally under the annular ligament and for a certain distance above it on the surface of the ulna. It is constricted under the annular ligament and expands above and below it. Its radial wall is, as it were, invaginated by the flexor tendons. There is thus a radially directed pocket in front, and another behind the tendons, opening into the sac, of course, on the ulnar side. But the wall of the sac is infolded round the superficial and deep set of tendons separately, so that there is a synovial recess between the two packets of tendons. It is, however, shallow and only extends as far as the tendons to the ring finger. The anterior and posterior pockets do not reach so far towards the fingers on the radial side of the palm, so that the tendons to the middle finger and, to a greater extent still, those of the index finger, are but slightly related to it. The posterior pouch extends higher up above the annular ligament than the anterior. In addition to the two main sacs there is very frequently a separate *intermediate* sac connected with the deep flexor tendon of the index finger. It commences at the carpal border of the radius, and extends distally for a variable distance

on the tendon. Another but inconstant sac occurs between the superficial and deep tendons of the index finger in the palm. The development of these palmar sacs is complicated. Under the anterior annular ligament there develop during embryonic life a radial sac, an ulnar sac, and eight others, one for each tendon of the digital flexors. The radial sac, that for the thumb, persists nearly unchanged, but the several flexor sheaths become connected with the ulnar sac to give rise to the complex arrangement seen in the adult. The intermediate sac is due to the persistence of the primitive sheath of the deep tendon to the index finger (Lucien).

THE MUSCLES AND FASCIÆ OF THE TRUNK

The muscles passing between the trunk and the upper limb have already been described. In this section the muscles which belong exclusively to the trunk will be treated of under three heads: (1) the dorso-lateral muscles or muscles of the back, and acting on the spine and head; (2) the ventro-lateral muscles or muscles of the body wall, and acting on the ribs and abdominal wall; (3) the muscles of the coccygeal region, with the cutaneous musculature comprising the perineal muscles.

DORSO-LATERAL MUSCLES AND FASCIA OF THE BACK

Between the trapezius, the latissimus dorsi, and rhomboid muscles, which form the first two layers of the muscles of the back, and the proper dorsal musculature, two muscles intervene which belong to the ventro-lateral group. These are the serratus posterior superior and serratus posterior inferior. They belong, morphologically and physiologically speaking, to the rib musculature, and will therefore be described with that. Here it will only be noted that the upper muscle is attached to certain of the upper, and the lower muscle to certain of the lower ribs, and both are fixed to the spines of the vertebræ by tendinous portions of the great dorsal sheet of fascia, just as is the latissimus dorsi.

Fasciæ of the Back.—The myotome columns in the early embryo are each surrounded by a connective tissue sheath which extends from the vertebral spines into the lateral region of the trunk. The fascial planes which develop from this connective tissue investment are important, as providing landmarks between the muscles derived directly and *in situ* from the myotomes, and those which in course of development have come to overlies them. The superficial lamella of the sheath or *vertebral fascia* extends from the skull to the back of the sacrum and coccyx. In the lumbar and sacral regions, owing to the interweaving of its fibres with those of the tendinous expansions of the latissimus dorsi and serratus inferior muscles, it becomes converted into a strong aponeurotic membrane, the **lumbo-sacral aponeurosis** or *posterior layer of the lumbar fascia*. This is attached medially to the lumbar and sacral spines and the supraspinous ligament, and laterally to the back of the iliac crest. In the lumbar region the aponeurosis is continuous round the lateral margin of the dorsal musculature, with a deeper layer attached to the ends of the transverse processes of the vertebræ (*middle layer of the lumbar fascia*). In the thoracic region the vertebral fascia is under cover of the trapezius and rhomboid muscles, which, as we have seen (p. 96), come to overlies the dorsal musculature during the course of development. At the upper end of the chest the fascia is again converted into the aponeurosis of the serratus superior; but between the two serrati it is a pure fascial lamella stretching between the vertebral spines and the dorsal surfaces of the ribs lateral to the ilio-costalis muscle. The fibres of the membrane are disposed transversely across the underlying muscles in accordance with the general rule. Some stronger superficial bundles possibly represent the intermediate suppressed portion of the serratus sheet. Above the level of the serratus superior the vertebral fascia is continued as a delicate layer over the splenius and semispinalis capitis to the head, and merges laterally with the general fascia of the neck. The deeper layer, mentioned above, which in the lumbar region finds attachment to the transverse processes of the vertebræ, is, like the superficial

lamella, in great part aponeurotic, providing the tendinous origin of the transverse muscle of the abdomen. It will be described along with that muscle, as will also a third layer continuous with it upon the ventral aspect of the quadratus lumborum (*anterior layer of lumbar fascia*).

Dorsal Muscles

The dorsal musculature of the trunk is covered by the vertebral fascia just described. It occupies the hollow between the vertebral spines and the prominences formed by the mastoid process, the cervical transverse processes, the most projecting parts of the ribs, and the crest of the iliac bone. It extends from the superior curved line on the occipital bone to the lower part of the sacrum. For convenience of description the musculature has been divided up into a large number of parts to which special names have been given. To a considerable extent this partition is artificial. The individual systems of fasciculi into which the musculature is resolved resemble rather the systems of fibres in a complex muscle than individualised muscles such as are met with in other parts of the body. If the musculature as a whole be examined from this point of view, it will be observed that the degree of individualisation is greatest in the region of the neck and is least in the region of the loins. The superficial systems of fasciculi stretch for considerable distances on the surface of the mass without attachment to the skeleton, the deeper systems have a shorter course between their attachments, while the deepest fibres extend only between adjoining vertebræ.

The several systems of fasciculi fall from a pure descriptive point of view into two groups, according as the component bundles run in a longitudinal direction between corresponding parts of the vertebræ or ribs, or are directed obliquely from the transverse processes to the spinous processes of the vertebræ. Both are continued to the head.¹ From the physiological point of view, and in so far as they act upon the spine, the longitudinal systems may be combined into a complex muscle, the *erector spinæ*, and the oblique into a second, the *rotator spinæ*. These physiological names, however, do not completely express the action of the muscles. The division into two contrasting systems is nevertheless useful, and here the old term *erector spinæ* will be retained for the longitudinal system and the term *transverso-spinalis* used for the oblique system of fasciculi. The splenius capitis is a specialised portion of the longitudinal system, and the complexus of the oblique system effecting movements of the skull on the vertebral column. But it is only when the musculature is studied from the developmental and morphological points of view, that its organisation becomes intelligible.

The dorsal musculature is derived directly from the myotomes. As already stated (p. 18), the septa between the myotomes disappear, and the formative material becomes fused into a continuous myotome column. But the fusion does not extend through the whole depth of the mass; in other words, the myosepta persist in the deep part of the column, but are overgrown by the primitive fibrillæ superficially, so that while the original segmental arrangement of the muscle fibres is retained in the strata immediately adjoining the vertebral column, it disappears entirely on the surface. The myotome column then becomes, by a process of cleavage, broken up tangentially into layers, and longitudinally into systems of bundles, which acquire connexions with the bony parts. In the superficial parts of the column the systems of fibres have a considerable span; but this diminishes from the surface inwards, until the layer is reached in which

¹ Certain strictly segmental slips, the intertransversales and the interspinales and the sub-occipital muscles, are excluded from this generalisation.

they extend over a single segment only. Further, the superficial fibres vary in length. In a general way the fibres become attached to homologous parts along the column, and are repeated serially. This serial repetition, however, no longer corresponds to the original myotomic segmentation, and moreover it is no longer regular.

In the lumbar and sacral regions the cleavage is not effected to the same degree as higher up. The original condition of the myotome column is largely retained. Over the thorax the cleavage into planes and longitudinal divisions is more completely carried out, while in the neck the primitive condition is still further departed from, by reason of the greater complexity in the arrangement of the components, and the greater extent to which the muscles are isolated and individualised. The greater complexity in the neck is due partly to the greater mobility of this part of the column, and partly to the provision of muscles for effecting the backward movements of the head on the vertebral column.

The dorsal musculature as a whole receives its nerve supply from the posterior divisions of the spinal nerves. When the distribution of the branches of supply is analysed, it is found that certain components are innervated by the lateral, others by the medial branches into which the posterior nerves divide. Accepting this fact as an indication of the original position in the myotome column of the material out of which the components are carved, we may group the muscles according as they are derived from a lateral or a medial division of the column. This morphological classification practically corresponds to the arrangement of the system according to the direction of the muscle fibres. Only one portion which is supplied by the medial branches of the nerves, the *spinalis dorsi*, requires to be separated from the other longitudinal components of the *erector spinæ*. As explained in the section on General Myology, the division of the myotome column according to nerve supply does not correspond to its primary division in development (see p. 19).

Splenius and Erector Spinæ.—The muscles of this group are derived from the lateral division of the myotome column. The splenius represents a superficial prolongation of the system to the head. It has become greatly broadened out and specialised, as compared with the other members in the group, in connexion with its action as an extensor and rotator of the head upon the vertebral column.

M. Splenius (figs. 59, 60). This muscle is so named from its having the form of a strap which binds down the parts lying under it. The muscle arises from the lower half of the *ligamentum nuchæ*, the spines of the seventh cervical and upper six thoracic vertebræ and the *supraspinous ligament*. The fleshy fibres spring directly from the *ligamentum nuchæ* above but mainly from an aponeurosis which gradually increases in breadth from above downwards—and are directed in parallel fasciculi upwards and lateralwards. The fasciculi are collected into two bands separated by a slight interval, which commonly extends into the aponeurosis and divides the muscle into two portions, named on account of their insertion *splenius colli* and *splenius capitis*. The *splenius colli*, much the smaller part of the muscle, comprises the bundles arising from the thoracic spines below the second. It winds round the neck, and becoming tucked in behind the lateral border of the upper portion of the muscle is inserted, with slips of the *elevator scapulæ*, into the transverse processes of the first two or three cervical vertebræ. The *splenius capitis* is a flat almost four-sided sheet of muscle, which is both broader and thicker than the *splenius colli*. It turns round the neck over the deeper muscles and is inserted into the lower part of the mastoid process, and into the lateral part of the superior curved line on the occipital bone.

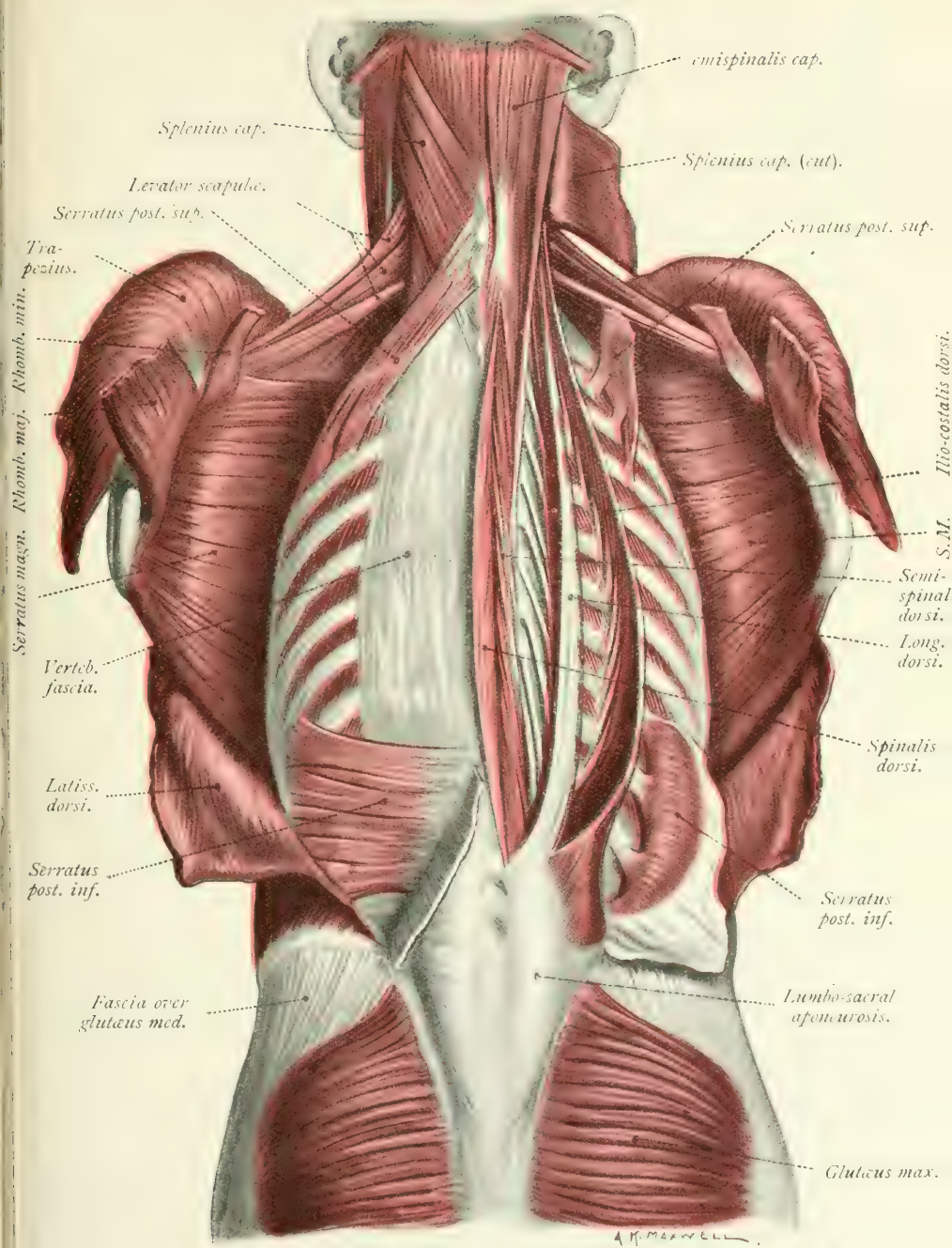


FIG. 59.—THE DORSAL MUSCULATURE EXPOSED BY REFLECTION OF THE SUPERFICIAL MUSCLES.

On the right side the dissection has been carried a stage further than on the left.

Relations. The splenius lies at its origin under the trapezius, rhomboids, and serratus posterior superior, at its insertions under the sterno-mastoid. Between the trapezius and sterno-mastoid the splenius capitis is exposed in the posterior triangle of the neck. It covers the deeper muscles.

Varieties.—The absence of the muscle has been noticed in two cases, both in individuals of coloured races (Testut, Le Double). Its origin may be moved upwards to the extent of one or two vertebrae, and not infrequently the origins of the opposite muscles do not exactly correspond. The two portions are sometimes quite separate, the superior part overlapping the inferior at its origin. Slips of connexion with the longissimus capitis, ilio-costalis, or levator scapulae are sometimes met with. The sheet is sometimes broken up into separate parts. Accessory slips are, in rare cases, seen passing superficial to the serratus posterior superior and more or less connected with the splenius. One such slip named *rhombo-atloideus* or *splenius colli accessorius* arises from the thoracic spines with the serratus superior, passes superficial to that muscle along the border of the splenius to be inserted on the transverse process of the atlas, or into the occipital bone or mastoid process. In this last form it might be termed *splenius capitis accessorius*. About the provenance of slips of this kind, and their relation to the splenius, there is difference of opinion.

The splenius, as already stated, represents a superficial prolongation of the lateral column of muscles to the head. Its attachment to the spines of the vertebrae is probably due to the extension backwards of the muscle, associated with a change in the direction of its fibres. This is supported by the fact that its nerves of supply are derived from the lateral branches of the posterior divisions of certain spinal nerves, and that these are, according to practically all authorities, limited to the cervical series.

M. Erector Spinae (fig. 59).—This is the name given to the remaining muscle components carved out of the lateral division of the myotome column. As the cleavage of the column has not taken place in the lumbo-sacral region, an undivided muscle mass is here found occupying the vertebral hollow. On the surface a great tendinous sheet has become developed, which extends over the whole lumbar and sacral regions. Over the back of the sacrum it is fused with the overlying lumbo-sacral aponeurosis, and lower down with the ligaments uniting the sacrum and coccyx, and also with the great sacro-sciatic (sacro-tuberosus) and long sacro-iliac ligaments at their attachments. Its bony attachments are to the lumbar and sacral spines, the lateral sacral tubercles, the posterior superior iliac spine, and the posterior part (about one-fifth) of the iliac crest. The fasciculi of which the tendinous expansion is composed pass upwards and a little lateral-wards. They are very short above the iliac crest, but become progressively longer as they approach the spines of the vertebrae so that the aponeurosis has an oblique lateral border. The tendinous bundles attached to the lumbar spines are frequently detached more or less from the aponeurosis. Fleishy fibres spring from the oblique lateral border and the deep surface of the tendinous expansion and form a bulky and powerful mass of muscle. Laterally the muscle fibres find direct attachment to the rough posterior part of the medial surface of the iliac bone and the iliac crest, beneath and lateral to the aponeurosis.

This muscle mass which represents the lateral division of the myotome column, is imperfectly separated on the medial side from a column of fleshy fibres representing the lower part of the transversospinalis, and therefore the inner division of the myotome column.

Just below the level of the last rib a division appears in the common muscle mass which separates it into two main portions, lateral and medial. The lateral column follows the line of the angles of the ribs, the medial column that of the transverse processes. For the purposes of description the first is named the *ilio-costalis*, the second the *longissimus*.

M. Ilio-Costalis (figs. 59, 60).—The ilio-costal muscle system extends from the iliac crest to the neck. It is continued upwards from the marginal part of the common muscle mass in the loins, and lies upon the ribs just medial to their angles. Along the lateral border the column is attached by a continuous series

of small flattened tendons, which appear on its superficial aspect, to the angles of the ribs and to the transverse processes of the lowest four or five cervical vertebræ. The column is divided longitudinally into two parts, lower and lateral (*lumbo-dorsal*) and upper and medial (*dorso-cervical*). The separation of the two parts is not always complete. They are generally connected by fasciculi common to both. The *lumbo-dorsal portion* is that to which the name *ilio-costalis* was originally given. It consists of the more superficial fleshy bundles springing from the iliac crest and lateral margin of the common tendinous expansion of the erector spinæ. These lumbo-dorsal fasciculi become exhausted on the slips for the lower six or seven ribs. The *dorso-cervical* portion of the column consists of an elongated flat muscular belly placed on the medial side of the lumbo-dorsal portion, and formed by the union of a continuous series of overlapping fleshy slips. These slips are attached by their narrow tendinous extremities to the upper borders of the lower nine or ten ribs just medial to the angles, that is on the deep aspect of the column. They are displayed by turning the muscle lateralwards. The slips of insertion for the upper ribs and cervical transverse processes leave the lateral border of this portion of the *ilio-costalis*, and arrange themselves in series with the lower set.

The B.N.A. divides what has been here called the dorso-cervical part of the *ilio-costalis* into the *ilio-costalis dorsi* and *ilio-costalis cervicis*. The two portions are in direct series, and their separation is more or less artificial. It introduces an unnecessary complication into the description. Moreover, the latter name suggests an origin from cervical myotomes, which is improbable in view of the supply of this part from the first and second thoracic nerves, with the occasional addition of the eighth cervical and third thoracic.

M. Longissimus (figs. 59, 60).—The longissimus system is larger and more powerful than that of the *ilio-costalis*. It consists of three parts—lumbo-dorsal, cervical, and cranial. The upper sections are more definitely separated from one another and from the main lumbo-dorsal portion, than in the case of the components of the *ilio-costalis*.

The *longissimus lumbo-dorsalis (dorsi)* is overlapped from the side by the *ilio-costalis* and is closely connected on the surface, medially, with the *spinalis dorsi*. The fleshy fibres arise from the deep surface of the tendinous expansion, the back of the iliac crest, and posterior sacro-iliac ligaments. The upper series of fibres springing along the line of the oblique lateral border of the aponeurosis and the iliac crest, are destined for the thoracic insertions, the lower and deeper series for the lumbar insertions. There are two series of these insertions, medial and lateral. The medial row is a series of tendinous slips attached to the transverse processes of all the thoracic vertebræ and the homologous accessory processes of the lumbar vertebræ. The lateral insertions form a series of thin fleshy tendinous processes along the lateral border of the muscle, which are attached in the thoracic region to the lowest nine or ten ribs, between their tubercles and angles, and in the lumbar region to the whole length of the transverse processes (costal processes) and beyond them to the lumbar fascia connected with them. Owing to the obliquity of the line along which the thoracic bundles spring from the common aponeurosis, it results that they are of approximately equal length.

The *longissimus cervicis* (fig. 60) muscle is a detached portion of the longissimus division of the lateral column, placed on the medial side of the lumbo-dorsal portion, and generally connected with it by tendinous slips. It arises from the transverse processes of the upper four or more thoracic transverse processes, and sometimes from the last cervical, and is inserted, along its lateral border by a series of tendinous slips, into the posterior tubercles of the transverse processes of the cervical vertebræ from the second to the sixth.

The *longissimus capitis* (trachelo-mastoid) (fig. 60) represents a further division of the longissimus continued to the head. It lies on the medial side of the last, and arises in close connexion with it from the upper thoracic transverse processes and from the articular process of the lower cervical vertebræ (3 or 5). These slips are united into a thin flat muscle which is inserted into the posterior margin of the mastoid process, under cover of the splenius and sterno-mastoid muscles. It is usually crossed by a tendinous intersection a little below its insertion.

Accessory Slips of Origin. When the tendinous slips attached to the lumbar spines are cut through, the deep medial surface of the lumbo-dorsal section of the longissimus is brought into view, and it is seen that it receives a variable number of slender accessory slips of origin. These come from the transverse processes of the lower thoracic vertebræ, or the mammillary processes of the lumbar vertebræ, or the aponeurosis of the underlying transversospinalis (Eisler). These may unite to form an independent muscle with a separate insertion into the upper two or three thoracic vertebræ, the *transversalis dorsi* of J. Müller and Luschka. Similarly accessory slips may be seen in the cervical section of the column arising from the roots of the transverse processes of the cervical vertebræ and forming, when more or less independent, the *transversalis cervicis posterior minor* of Luschka.

The attachments of the components of the longissimus are subject to considerable variation. The costal attachments may be reduced either at the cranial or caudal end of the series; the longissimus cervicis may be continued down to the tenth or eleventh transverse process, or its slips may be reduced in number. The cranial section may be absent; its slips may be extended on the thorax, or confined to the cervical vertebræ. It has been seen divided into two parts. Slips detached from the longissimus capitis have been observed coming from the transverse process of the atlas, or tendon of the cervical portion going to the atlas, and inserted into the mastoid process (Eisler, Chudzinski).

M. Spinalis Dorsi (fig. 59). This is a long narrow muscle placed on the medial side of, and closely connected with, the longissimus. It receives slender tendinous fasciculi from the lowest two or three thoracic spines, and others from the upper two or three lumbar spines, which are common to it and fibres of the longissimus. Its insertion takes place into a variable number of the upper thoracic spinous processes, the slips being closely adherent to the subjacent transversospinalis. The lumbar slips wind round the higher slips of origin and are attached lower down.

This muscle is often, as in the last edition of this work, described as a third division of the erector spinæ. It is intimately connected with the longissimus, and inasmuch as the fasciculi are longitudinal, its action will be, in co-operation, of course, with the muscle of the opposite side, the same as that of the other longitudinal systems. It is, however, supplied by the medial branches of the posterior divisions of the spinal nerves (Eisler), and it is only a part of a continuous series of spinal slips, which are usually suppressed in the lumbar and cervical regions, but may appear as varieties. It may be considered for these reasons to represent the superficial division of the medial column, not differentiated in the lumbar region from the longissimus.

The *spinalis lumborum* is a rare variety consisting of some slips from the lumbar spines, which are inserted into the lower thoracic spines with the transversospinalis. The *spinalis cervicis* (fig. 61) is an inconstant muscle arising variably from the seventh cervical spine or one or two spines above or below this, and inserted chiefly into the spine of the axis, occasionally also into those of the third and fourth cervical vertebræ.

The name *spinalis capitis* is sometimes given to the bundles of muscle fibres which frequently come from the cervical or thoracic spines and join the complexus on the view that they belong to this series.

Complexus and Transverso-Spinalis.—The complexus bears the same relation to the medial division of the myotome column as the splenius does to the lateral division. Like the splenius it has become greatly broadened out, and specialised in connexion with the movements of the head on the vertebral column.

M. Complexus (semispinalis capitis), or transverso-occipitalis (Hans Virchow) (figs. 59, 60, 61). The complexus is a considerable sheet of muscle of

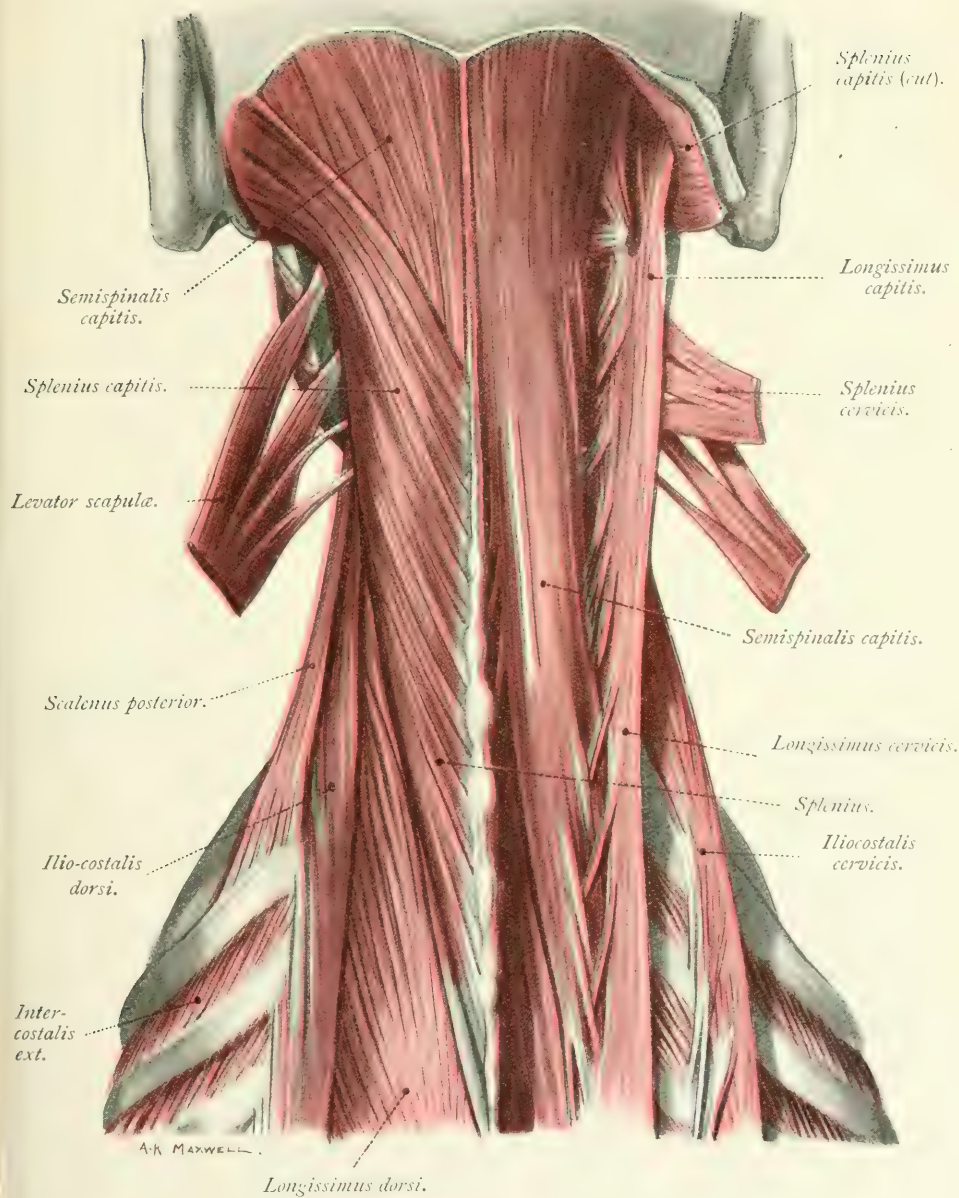


FIG. 60.—THE DORSAL MUSCLES IN THE NECK.

somewhat triangular form placed under the splenius except at its upper extremity. Its medial border in the neck is in contact with the ligamentum nuchæ. It arises by tendinous slips from the transverse processes of the upper six or seven thoracic vertebræ and that of the last cervical, and also from the articular processes and bases of the transverse processes of the cervical vertebræ as high as the third. It is also frequently joined by one or two slender fasciculi from the lowest cervical and highest thoracic spines. It is inserted into the large medial impression between the nuchal lines on the occipital bone. An irregular, commonly incomplete, tendinous intersection crosses the muscle about the level of the spine of the axis, while another larger one interrupts the fibres of the medial part of the muscle lower down, on the level of the sixth cervical to the second thoracic spine. This lower medial portion of the muscle is more or less separated from the lateral part on account of the way in which the muscular fibres converge on the intersection, and was formerly described as an independent muscle under the name of *biventer cervicis*.

Relations.—The complexus muscle is covered by the splenius, except at its lowest origins from the thoracic vertebræ, and at the medial portion of its upper extremity where it lies directly under the trapezius. The longissimus capitis and longissimus cervicis rest upon its series of origins, and the semispinalis cervicis, the posterior recti, and the obliqui capitis, together with the deep cervical vessels, are concealed by it.

Varieties.—The slips of attachment vary considerably in the direction of either increase or decrease. It receives accessory slips sometimes from the longissimus or spinalis dorsi. A rare variety is the presence of a second lamella under the medial portion of the muscle extending from one or more of the upper thoracic spines to the occipital bone.

M. Transverso-Spinalis.—This complex muscle system includes the remaining components of the medial column. It occupies the angle between the spines of the vertebræ and the transverse processes, and forms a continuous column from the axis to the sacrum. The column is composed of fibres which all arise from the transverse processes and are inserted into the spinous processes of the vertebræ. But it must be noted that the fibres springing from each point of origin spread at their insertion over a number of vertebræ, and that the superficial fibres are the longest and most oblique, while the deepest fibres are quite short, extend only to the vertebra next above, and are nearly horizontal in direction. It follows that the fibres overlap and intercross with one another in an intricate fashion.

The column can be resolved into three layers, for descriptive purposes, although the separation is largely an artificial one. The first layer consists of the most superficial, the longest, and most oblique bundles, and is known as the semispinalis. The shorter, deeper fibres form a continuous column, which has been named the multifidus spinæ, on account of the way in which it is broken up into bundles of fleshy and tendinous fibres with varying degrees of obliquity, interwoven with one another. The deepest segmental bundles may be comprised under the category of the submultifidus of A. W. Hughes.

The **semispinalis** (fig. 59) muscle consists of bundles of oblique fibres extending from the transverse processes to spines, and crossing over from four to six vertebræ. It arises by tendinous slips from the transverse processes of the upper ten thoracic vertebræ, and is inserted into the spinous processes of all the vertebræ from the axis to about the sixth thoracic. Its origin may extend to the transverse process of the eleventh, or mammillary process of the twelfth vertebra, and the number of slips of insertion varies. The fibres from one point of origin are distributed to several spines.

The portion of the sheet arising, roughly, from the upper six thoracic transverse

processes is named the **semispinalis cervicis** (fig. 61), and the part springing from the lower six the **semispinalis dorsi**. The two parts are directly continuous serially with one another, unless an intermediate slip has dropped out. The slip to the spine of the axis is specially stout.

According to Eisler the semispinalis may, in rare cases, be differentiated from the multifidus in the lumbar region. It takes the form of a series of slips, arising indirectly by a fascial lamella from the mammillary processes of the second lumbar to the first sacral vertebra, and directly from the corresponding processes of the first lumbar and twelfth thoracic vertebrae, and passing to be inserted into the lower thoracic spines.

The **multifidus spinæ** muscle (fig. 61) extends from the axis vertebra to the level of the fourth sacral segment. The same general arrangement of the constituent fasciculi prevails along the whole length of the vertebral column. The muscle mass is more largely developed towards the lower end than at the upper end of the spine, and is thinnest in the thoracic region. In the sacral region the fibres arise from the deep surface of the tendinous expansion described with the erector spinæ, from the groove on the back of the sacrum, as low as the fourth foramen, from the medial part of the posterior extremity of the iliac bone, and the posterior sacro-iliac ligaments. In the lumbar region the slips arise from the mammillary processes; in the thoracic region from the transverse processes; and in the neck from the articular processes of the four lower cervical vertebrae. From these several points of origin the muscular bundles ascend obliquely to be inserted into the spines of the vertebrae from their bases to their extremities. The fibres from each point of origin are fixed to several vertebrae, the deepest ones being inserted into the side of the spinous process the next but one above, the others ascending more and more vertically as high as the fourth vertebra from the place of origin. The longer fibres from one origin overlap those from the origin next above.

Submultifidus.—Under this title Hughes included a succession of deep slips which can be dissected out beneath the multifidus in all the regions of the spine. They are best developed in the thoracic region, were first noticed in this region, and named the **rotatores dorsi** muscles. There are eleven on each side, and each springs from the upper and back part of the transverse process of one vertebra, and is inserted into the lower margin of the lamina of the vertebra next above. The direction of the fibres is nearly horizontal. In association with these, but not recognised as independent of the multifidus by most observers, are the *rotatores longi* of Henle. Each of these arises, along with the short rotator, from the transverse process and ascending more vertically is inserted into the root of the spine of the vertebra next above, thus springing over one vertebra. Somewhat similar, but more variable and irregular bundles, are generally present in both the cervical and lumbar regions. The whole series are to be regarded as the deepest slips of the multifidus.

M. Interspinales.—These small muscles are short vertical fasciculi of fleshy fibres, placed in pairs between the spinous processes of the contiguous vertebrae. In the *cervical region* from the axis downwards they are roundish bundles attached to the two parts into which the spinous processes are divided. Longer bundles are sometimes found passing over one or two vertebrae (*interspinales longi*), and forming a transition to the spinalis cervicis already described. In the *thoracic region* the interspinal muscles are represented only by slender slips in one or two of the highest and lowest spaces. In the *lumbar region* they are flattened bands one on each side of the interspinous ligament and extending the whole length of the spinous process. They are generally fused with the deep segmental slips

of the multifidus, which cross them at the roots of the spines. In the *sacral region* the muscles are absent, except in the space between the spine of the first segment and the last lumbar spine.

Suboccipital Muscles (fig. 61). This group includes four small muscles extending between the axis and atlas vertebræ and the occipital bone, and separated from the overlying complexus, longissimus capitis, and splenius capitis by a distinct fascial layer of some density.

The **rectus capitis posterior major** muscle arises by a narrow tendon from the spinous process of the axis, and expanding as it passes upwards and laterally, is inserted into the lateral part of the inferior curved line on the occipital bone. Its insertion is medial to and beneath that of the superior oblique muscle.

The **rectus capitis posterior minor** muscle arises from the posterior arch of the atlas by the side of the tubercle, and expands as it passes upwards to be inserted into the medial third of the inferior curved line on the occipital bone and the depression between it and the foramen magnum.

The **obliquus capitis inferior**, the strongest of the four suboccipital muscles, arises from the spine of the axis vertebra, between the origin of the rectus posterior major and the insertion of the semispinalis cervicis, and is inserted into the lower and back part of the transverse process of the atlas.

The **obliquus capitis superior**, smaller than the preceding muscle, arises from the upper surface of the transverse process of the atlas, and is inserted into an impression between the lateral parts of the curved lines on the occipital bone. The muscle is directed upwards and medially and expands at its insertion, where it overlaps the insertion of the rectus capitis posterior major.

The two oblique muscles with the rectus major form the sides of a small triangular space, the *suboccipital triangle*, in the area of which the posterior primary branch of the suboccipital nerve and the vertebral artery are found.

Nerves of Supply.—The four suboccipital muscles receive their nerve supply mainly from the suboccipital nerve, *i.e.* the posterior division of the first cervical nerve. The superior oblique receives a lateral twig from the nerve, the others medial branches. Filaments come also, in the case of the inferior oblique, from the second cervical nerve in several minute twigs which enter its lower border and dorsal surface (Eisler).

Varieties.—Longitudinal division or doubling of the recti muscles is not infrequent. Doubling of the oblique muscles is less common. Accessory slips are sometimes found passing in continuation of the spinalis cervicis from the spines of one or two of the cervical vertebræ and ligamentum nuchæ to the occipital bone. A rudimentary muscle has been observed passing from the spine of the axis to the mastoid process, along the lateral border of the inferior oblique. The *atlanto-mastoid* is a small muscle, often present, arising from the transverse process of the atlas, between the obliquus superior and rectus lateralis and inserted into the hinder part of the mastoid process.

Of the suboccipital muscles the two recti and inferior oblique are developed (Bardeen and Lewis) from a common rudiment, the superior oblique being a separate element. According to the classical theory, the muscles are formed by a special differentiation of the deeper portion of the medial division of the myotome column, in relation to the movements of the head. The mass between the skull and the first two vertebræ is first divided in reptiles into medial (rectus) and lateral (obliquus) portions, the place of division being marked by the entrance of the posterior division of the suboccipital nerve, which represents a medial branch only. A further division occurs in each of these portions, in the medial by the separation of the fibres attached to atlas and axis respectively giving origin to the two recti, and in the lateral, by a connexion being formed with the transverse process of the atlas. As the transverse process acquires a much greater prominence in mammals, it carries out with it the two sections of the lateral band which form the oblique muscles, leaving between them and the rectus major the interval known as the suboccipital triangle. Eisler regards the nerve to the superior oblique as a lateral branch and finds support for the detachment of this muscle from the others in its separate development. He groups it with the atlanto-mastoid and lateral part of the rectus lateralis as the equivalent of a dorsal intertransverse muscle, the recti and inferior oblique coming into the interspinal group.

M. Intertransversales.—The intertransverse muscles are short fleshy bundles which pass nearly vertically from vertebra to vertebra between the transverse processes. Although for convenience they are included in a section by themselves, they do not form a single morphological group. Some are supplied by the ventral divisions, others by the dorsal divisions of the spinal nerves, and belong, therefore, to the ventral and dorsal musculature respectively.

In the **cervical region** there are two rounded fleshy bundles below each transverse process, the one descending from the costal, the other from the transverse process. The anterior slips are placed ventral to the issuing ventral roots of the spinal nerves, and receive minute branches from them. The first is often reduced to a small bundle or is absent altogether. Each dorsal slip, according to Eisler, consists of two portions separated from one another by the dorsal branch of the spinal nerve as it passes dorsalwards. The medial part is supplied by the dorsal branch, the lateral portion by the ventral branch of the spinal nerve. The lateral portions, therefore, although united with the medial, correspond to the lateral intertransverse muscles of the loins, and belong like them to the latero-dorsal portion of the ventral musculature. They vary much in degree of development, but the first three are generally well marked. The posterior intertransverse muscles proper begin at the atlas and are present in all the spaces. The last is connected with a bundle going to the neck of the first rib from the transverse process, and is therefore in part a costo-transverse muscle (Eisler).

In the **thoracic region** the intertransverse muscles are represented by small fleshy bundles in the lowest three or four spaces; in the middle spaces they are replaced by small tendinous bands (intertransverse ligaments); in the upper spaces they are usually altogether wanting. In the first space Eisler describes a delicate muscle which passes medial to the lateral branch of the posterior spinal nerve, and a stronger slip which is placed lateral to the nerve and extends between the first thoracic transverse process and the neck of the second rib.

In the **lumbar region** there are again two sets of intertransverse muscles, medial and lateral. The medial intertransverse slips pass from the accessory process of one vertebra to the mammillary process of the next, and receive their nerve supply from the dorsal nerve trunks, by minute branches which come off before the dorsal branch divides. The lateral intertransverse muscles lie between the transverse processes, the first arising from the lateral tubercle on the twelfth thoracic vertebra, and ending on the first lumbar transverse process, and the last extending between the fifth lumbar transverse process and the ala of the first segment of the sacrum. Their nerve supply comes from the ventral divisions of the spinal nerves. They are placed in direct series with the levatores costarum, and with the quadratus lumborum they represent the latero-dorsal portion of the ventral musculature of the lumbar region of the trunk.

Action of the Muscles on the Spinal Column.—The movements of the spinal column are flexion and extension, lateral bending to either side, and rotation in both directions round a vertical axis. The movements are the sum of small displacements between the individual vertebræ, and hence the common characters of the muscles of the spine are their subdivision and the multiplicity of their attachments.

In the upright position there is a tendency towards flexion, since the line of gravity of the head and upper limbs lies in front of the vertebral column. The extensor muscles control the movement of flexion, and hence their proportionately large size (2:1) as compared with the flexors. (In the anthropoids the proportion is reversed, the flexors being twice as powerful as the extensors, Fick.) Under ordinary conditions in the erect posture, therefore, the flexors and extensors of the spine act against gravity, and remain in a state of "vigilant repose" (Adams);

if the body tends to fall backwards the flexors contract, and if it tends to fall forwards the extensors contract.

The active flexors of the spine are the muscles of the abdominal wall, the recti and obliqui externi and interni. These muscles, acting through the long lever arm of the thorax, bend the spine directly forwards when the muscles of both sides act, but incline it laterally when they act on one side only. Their action is well seen, and is best tested in the position of lying flat on the back, a flexion forwards of the head being sufficient to call them into action. The complete movement of sitting up from the lying position consists of two stages; in the first the thorax is bent forwards on the pelvis by the abdominal muscles, and in the second the pelvis with the spine is flexed on the thighs by the psoas, iliacus, and other flexors of the hip. The spine may be fixed by the extensors and then flexed by the hip muscles if the abdominal muscles are paralysed. The longus colli and scaleni muscles are flexors of the cervical spine when both sides act together; when those of one side act alone the spine is bent laterally to that side.

The active extensors of the spine are the different parts of the erector spinæ, the action of which can be seen best by making a person lie prone and lift up the head and upper part of the trunk. When it acts as a whole and on both sides, the "fixed point" is at the base of the sacrum, and the whole column is evenly extended from the flexed position to the erect position; beyond this position, as already explained, extension of the spine is performed by the weight of the body and the regulated relaxation of the flexor muscles, the erector spinæ being relaxed. The quadratus lumborum muscles are weak extensors of the lumbar spine; if the muscle of one side acts alone the spine is bent to that side.

The rotation muscles are the oblique muscles of the abdominal wall and the oblique parts of the erector spinæ, those parts of opposite obliquity on the two sides acting together. Rotation movements do not occur in the lumbar region.

The lateral movements are effected by the flexor and extensor muscles of one side contracting together.

Movements of the Head.—The movements of the head on the spinal column are: (1) flexion and extension (nodding movements) and, in very small amount, movements of lateral inclination. These movements are usually associated with, and much increased by, accompanying movements of the cervical spine. (2) Rotation movements from side to side.

The movement of flexion is performed ordinarily by the weight of the head, since the axis of gravity of the head lies slightly in front of the transverse axis of movement at the atlanto-occipital joints; and, acting against the weight of the head, movement is carried out by a regulated relaxation of the extensor muscles. The movement of extension is initiated by the extensor muscles, but after the weight of the head has been carried behind the axis of gravity the further movement is controlled by the flexor muscles.

Active flexion is performed by the sterno-mastoid¹ and longus capitis muscles and the two small muscles, the rectus capitis anterior and the rectus lateralis. These muscles flex the head directly forwards when both sides act together, but bend it obliquely when those of one side act alone. The sterno-mastoids are the chief flexors and their action is seen best when a person lying flat on the back raises the head. When they contract powerfully the rectus muscles of the abdominal wall contract to fix the sternum (Winslow), and the depressors of the hyoid bone also contract.

Active extension of the head is carried out by the contraction of the upper parts of the trapezius muscles and the splenius capitis, the semispinalis capitis, longissimus capitis, rectus capitis posterior major and minor, and obliquus capitis superior muscles. The sterno-mastoid muscles have been described to act as extensors in extreme extension (Duchenne), but this is probably incorrect.² In the usual position of the head the extensor muscles must act to prevent passive flexion taking place.

The movements of rotation are combined with a certain amount of sinking of the head on the side opposite to that to which it is being turned, and at the same time it is tilted a little backwards (Vol. IV., Part I., p. 229). This compound displacement depends on the mechanism of the atlanto-axial joint. The muscles which effect these rotation movements of the head, say turning the face towards the right side, which is accompanied by a bending of the head to the left side, are the left sterno-mastoid and the upper part of the left trapezius, and with these there are associated the right splenius capitis and the right platysma. The right omo-hyoid also contracts, possibly to ensure that the hyoid bone moves round with the chin.

¹ The flexion action of the sterno-mastoid muscles has been often questioned (Meyer, Henle, Fick, Morris).

² Winslow, Cruveilhier, Beevor.

VENTRO-LATERAL MUSCLES OF THE TRUNK

The group of muscles now to be considered form the proper muscles of the walls of the body cavity. From the purely descriptive point of view they fall into two groups, the intrinsic muscles of the thorax and the muscles of the abdominal wall. They are the serrati posteriores, the intercostal muscles, the levatores costarum, transversus thoracis and the subcostal muscles, the two oblique muscles of the abdominal wall, the transversus abdominis, the rectus abdominis, and pyramidalis. All are derived from the thoracic myotomes with a certain contribution from the first and a small contribution from the second lumbar, and they constitute therefore, morphologically speaking, a single group.

As has already been explained (p. 21) the latero-ventral musculature of the lumbar region is not represented in the trunk except to a very slight extent. The dorsal portion of the primitive ventral sheet provides the quadratus lumborum and the lateral intertransverse muscles of the loins. The thoracic part of the latero-ventral section of the sheet, on the other hand, has extended beyond the region of the ribs, has acquired connexions to the pelvic girdle, and has been utilised to form the muscular layers of the ribless abdominal wall. The musculature consists of a lateral series of muscles in which the constituent fibres are arranged obliquely or transversely to the axis of the trunk, and a median set in which the direction of the fasciculi is vertical (cranio-caudal). The lateral muscles are arranged in three layers. In the first or outer layer the fibres are, generally speaking, directed obliquely downwards and forwards. This layer is subdivided over the thorax into a superficial lamella on the surface of the ribs, and a deep lamella which, confined between the ribs, has retained the original myotomic segmentation. In the abdominal wall the two lamellæ are not separated. The outer lamella extends to the upper end of the thorax in some lower mammals, but is reduced in man, owing to the extension of the limb musculature over the trunk. The second or middle layer consists of the internal oblique muscle of the abdominal wall and the internal intercostal muscles (see below), in which the fibres course upwards and forwards. The third or internal layer consists of the transversus abdominis, and the subcostal group of muscles in the thorax including the intra-costal or innermost lamellæ of the so-called internal intercostal muscles. The ventral median group, comprising the rectus and pyramidalis muscles, extends, in lower mammals, the whole length of the thorax, but in man it has undergone reduction, like the thoracic part of the external oblique muscle. The quadratus lumborum is derived from the dorsal portion of the lumbar section of the ventro-lateral sheet of muscle.

The Muscles of the Thorax

Serrati Muscles (fig. 59, p. 165).—The serrati muscles lie under the muscles passing to the pectoral girdle and limb from the vertebral column. The superior serratus is in contact, except at its upper medial angle where its aponeurosis lies directly under the trapezius, with the levator scapulae and the rhomboid muscles. The inferior is completely under cover of the latissimus dorsi muscle.

M. Serratus Posterior Superior.—The serratus superior is a thin flat muscle which arises by a broad aponeurosis from the ligamentum nuchæ, the spines of the last cervical and two or three thoracic vertebræ, and from the supraspinous ligament, and is inserted by four fleshy digitations into the second, third, fourth, and fifth ribs. The aponeurosis forms nearly half the length of the muscle, and extends from the spines as far as the ends of the transverse

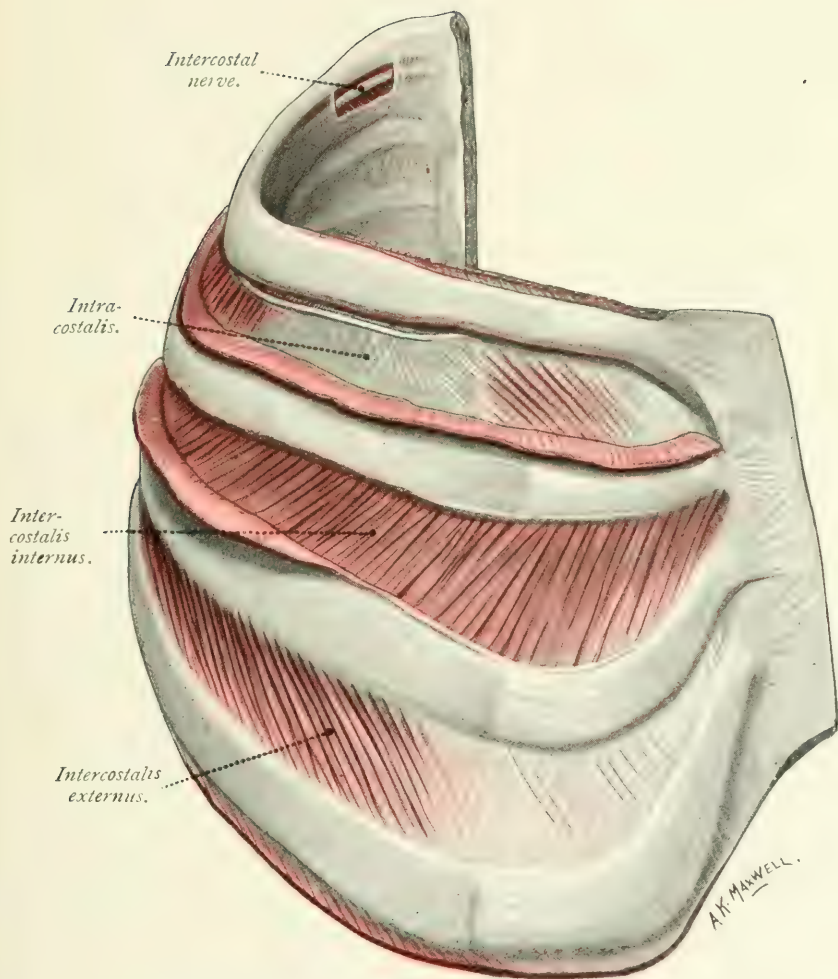


FIG. 62.—DISSECTION OF THE INTERCOSTAL MUSCLES IN THREE SPACES FROM THE FRONT. (Walmsley.)

processes. The fasciculi are directed obliquely downwards and laterally, and are inserted into the upper borders and outer surfaces of the ribs.

M. Serratus Posterior Inferior. The serratus inferior is a broader and stronger muscle than the superior. It is attached to the spines of the last two thoracic and first two lumbar vertebræ by a thin aponeurosis which is closely united with the aponeurosis of the latissimus dorsi. The muscular bundles spring from the aponeurosis along an irregular line, and, directed upwards and lateralwards, are attached by four digitations to the lower borders of the last four ribs. The fleshy digitations are shorter than the aponeurotic part of the muscle, and they overlap one another from above downwards. The last slip varies in size with the length of the twelfth rib, and is often entirely concealed by the one above it. In a good many instances aberrant bundles occur which, changing their direction, are inserted into the outer surface of the succeeding rib.

Varieties of the Posterior Serrati.—There is considerable variation in the number of the digitations. The number of the slips of the serratus superior may be reduced to three, or less frequently increased to five or six slips. The serratus inferior may be reduced to two digitations, the first and the last failing. Absence of the superior or of the inferior muscle has been recorded, in the sense that they are replaced by fibrous tissue (Le Double), but this seems extremely rare. Cases have been described in which the serratus inferior showed irregular arrangements of the digitations, or accessory bundles in connexion with it (Eisler).

The character of the variations of the muscle, and the fact that the superior serratus extends over the interval between it and the inferior serratus in some of the lower mammals, suggest that the two muscles represent the upper and lower parts of what was once a continuous sheet (Gegenbaur). According to Maurer, however, the serratus inferior is separate and lies deep to the extended serratus superior, when that is present. He refers the inferior belly to the internal oblique sheet on grounds which cannot be entered upon here.

The **levator costarum** muscles (figs. 61, 65) are twelve in number on each side. They lie under cover of the ilio-costalis and longissimus muscles, rest on the posterior intercostal membrane, and are continuous at their lateral borders with the external intercostal muscles. They arise from the tips of the transverse processes of the seventh cervical and the upper eleven thoracic vertebræ, and are inserted into the outer surfaces of the ribs between their tubercles and angles. Each levator costæ is a fan-shaped slip, and corresponding in direction with the external intercostal muscle, it passes downwards and lateralwards, spreading as it descends, to be attached to the rib below that belonging to the vertebra from which it springs. The levator muscles in the upper spaces preserve a strictly segmental arrangement, but in the lower four spaces additional bundles of fibres are present, each of which passes over one rib to be attached to the next below. These bundles are sometimes distinguished as *levator costarum longi*. They are occasionally present as slender slips even in the upper spaces.

The levatores costarum are in direct series with the lateral intertransverse muscles of the loins, and represent, as these do, the most medial part of the latero-dorsal division of the ventrolateral musculature, in which the original myotomic segmentation has been retained.

M. Intercostales.—Before entering on the description of these muscles it is necessary to give some explanation of the nomenclature employed. It has been demonstrated by Eisler, Delmas, Walmsley, and Forster, that each internal intercostal muscle of the classical descriptions is really compounded of two parts, one lateral, one medial, to the internal or main branch of the intercostal nerve. The part external to the nerve is confined to the ventral part of the intercostal space, and is replaced dorsally by a membranous lamella. The portion deep to the nerve forms a complete fleshy lamella dorsally, but except in the lower spaces ends a little beyond the middle of the space and is replaced by a fascial lamella. This layer may be incomplete or absent in the upper spaces, and it is always merged with the so-called subcostal muscles which are, in so far as they have an independent existence, only detached portions delaminated from it. Eisler, who was the first to show the meaning of the relations of the intercostal nerve to the muscle layers,

named the lamella external to it the *M. intercostalis intermedius*, and that internal to it *M. intercostalis internus*. As the intermediate layer undoubtedly corresponds to the internal oblique and is continuous with it in the lower spaces, it seems much better to reserve the name internal intercostal for it, as is done by Walmsley and Forster. The innermost layer was named *intracostalis* by Walmsley, but by Forster it is simply termed *subcostalis*. The term *intracostalis* is to be preferred, as it avoids, by introducing a distinctive name, any confusion with former descriptions of the muscles.

M. Intercostalis Externus (figs. 62, 63).—The external intercostal muscles intervene between the ribs. They extend, generally speaking, from the tuberosities of the ribs to the lateral ends of the cartilages, and are directed obliquely downwards and forwards from the prominent lower margin of one rib to the upper border of the next. These fibres are interrupted by tendinous bundles to a considerable extent, but without any regular alternation. They are thicker behind, and thin away at the front. In the first intercostal space the muscular fasciculi generally extend beyond the ends of the ribs, but in the following three or four they do not quite reach the ends of the ribs; in the lowest two intervals they are continued forwards along the lower cartilages. Beyond the point at which the muscles cease the spaces are occupied by thin shining membranes in which the fibres have the same direction as those of the muscles with which they are continuous. These *anterior intercostal membranes or ligaments* thus replace the external intercostal muscles between the cartilages, and cover the deeper intercostal lamellæ. Occasionally the muscles extend further than usual and may even reach the side of the sternum. Sometimes an intercostal muscle, most frequently the last, may be entirely replaced by tendinous fibres. An interchange of fibres with the external oblique is not infrequently seen.

The **supracostalis** muscle is a slip occasionally seen passing from the ventral end of the first rib downwards to the fourth, sometimes also to the second and third ribs. It has been found connected above with the deep fascia of the neck, or with the scaleni muscles. Other occasional slips placed dorsal to the origin of the serratus anterior (*supracostalis posterior*, Eisler), and occurring singly or combined, come into the same category as the ventral slip just described. They are all to be considered as remnants of the superficial lamellæ of the primitive external oblique muscle sheet, and to be classed with the serrati posteriores in this respect.

M. Intercostalis Internus (figs. 62, 63).—The internal intercostal muscles extend from the ventral ends of the intercostal spaces for a variable distance dorsalwards. Thick ventrally, they are reduced to a single layer of muscle fibres which disappear about the middle of the intercostal space, and are continued by a fibrous lamella to the dorsal end of the space. The fleshy portions of the internal intercostals are less interrupted by tendinous fibres than are the external intercostals. The fibres are directed downwards and backwards, instead of downwards and forwards. In the lower spaces they are continuous with the fibres of the internal oblique muscle of the abdomen. The membrane which in each space continues the fleshy fasciculi, is attached along the lateral lip of the subcostal group external to the nerve. This attachment is preserved by the fleshy part, but more ventrally the fasciculi are fixed to the lower border of the rib or cartilage. The fibres are attached along the upper border and slightly on the inner surface of the lower rib in each space.

M. Intracostalis (figs. 62, 63).—The intracostal muscles are placed internal to the intercostal nerves and are intimately united with the subcostales. The fasciculi partly intervene between the borders of the ribs and partly extend on to their inner faces. They are present in all the intercostal spaces except the first. They are confined to the dorsal part of each space, down to a variable point, but never in the case of the true ribs as far as the level of the ribs with their cartilages. The

fibres are directed like those of the internal intercostal, and are attached to the upper border of the subcostal groove of the rib above internal to the nerve, and the upper border and inner surface of the rib below. In addition to these shorter fasciculi, and intimately connected with them, there are others chiefly in the neighbourhood of the angles of the ribs which extend over one or two intercostal spaces. They are more constant in connexion with the lower ribs and have been named the *subcostal muscles*. These two systems of fibres belong, with the muscle next to be described, to the innermost transverse layer of the body wall, even although the fibres are not transverse in direction, but agree in their course with the fibres of the internal intercostal. It is to be noticed, however, that in the lower spaces the fasciculi more nearly approach the horizontal.

M. Triangularis Sterni (fig. 65).—The B.N.A. name for this muscle is *transversus thoracis*. It was apparently given that title because it was considered to represent in the thorax the transversus abdominis. We now know that the intracostalis and subcostalis systems equally deserve the name transversus thoracis, so that the old name given to the muscle on account of its form should be preserved. It consists of a thin stratum of muscular and tendinous fibres, placed within the thorax behind the costal cartilages. It is very variable as to its extent and points of attachment in different bodies, and even on the opposite sides of the same body. It arises in typical cases by tendinous fibres from the back of the metasternum and lower part of the mesosternum, and from the cartilages of the lower three or four true ribs. Its fasciculi pass upwards and lateralwards in a diverging manner, the lowest being horizontal, the middle oblique, and the upper more nearly vertical. They are inserted by separate slips into the lateral ends of the costal cartilages, sometimes also into the bony ribs, from the second to the sixth inclusive. At the lower margin the fibres are in the same plane as those of the transversus abdominis, with which the muscle is connected at its origin, and of which it is a continuation upwards.

Relations.—The internal mammary vessels pass between the anterior surface of the muscle and the costal cartilages. Its deep surface is in contact with the pleura, and on the left side also with the pericardium.

Varieties.—Occasionally it is prolonged to the first rib. Absence on one or on both sides has been recorded. It is sometimes divided into separate fasciculi, and its division into two lamella has also been observed. It is sometimes easy to demonstrate a fascial continuity between the triangularis and the upper intracostales.

Nerves of the Thoracic Muscles.—The external intercostal muscles are supplied by long slender branches which come off from the intercostal trunks as far back as the tubercles of the ribs. Each muscle is supplied by its own segmental nerve. From the branches to the external intercostals, twigs come off in the first four spaces which pierce the muscles and go to the serratus posterior superior. A branch from the ventral division of the eighth cervical nerve is frequently found piercing the scalenus medius to reach the upper part of this muscle (Fisler). The serratus inferior receives its supply from the ninth, tenth, and eleventh thoracic nerves through the intercostal trunks, the twigs of distribution piercing the external intercostals. The branches of supply for the levatores costarum muscles come from the intercostal trunks, except in the case of the first which receives its nerve from the eighth cervical. The internal intercostal muscles, the intracostals, the subcostals, and the triangularis sterni are supplied by the main branches of the intercostal nerves, the last named receiving its branches from the second to the sixth thoracic nerves.

In connexion with the rib musculature it is convenient to describe the diaphragm, although it has no relation except a physiological one to the costal muscles.

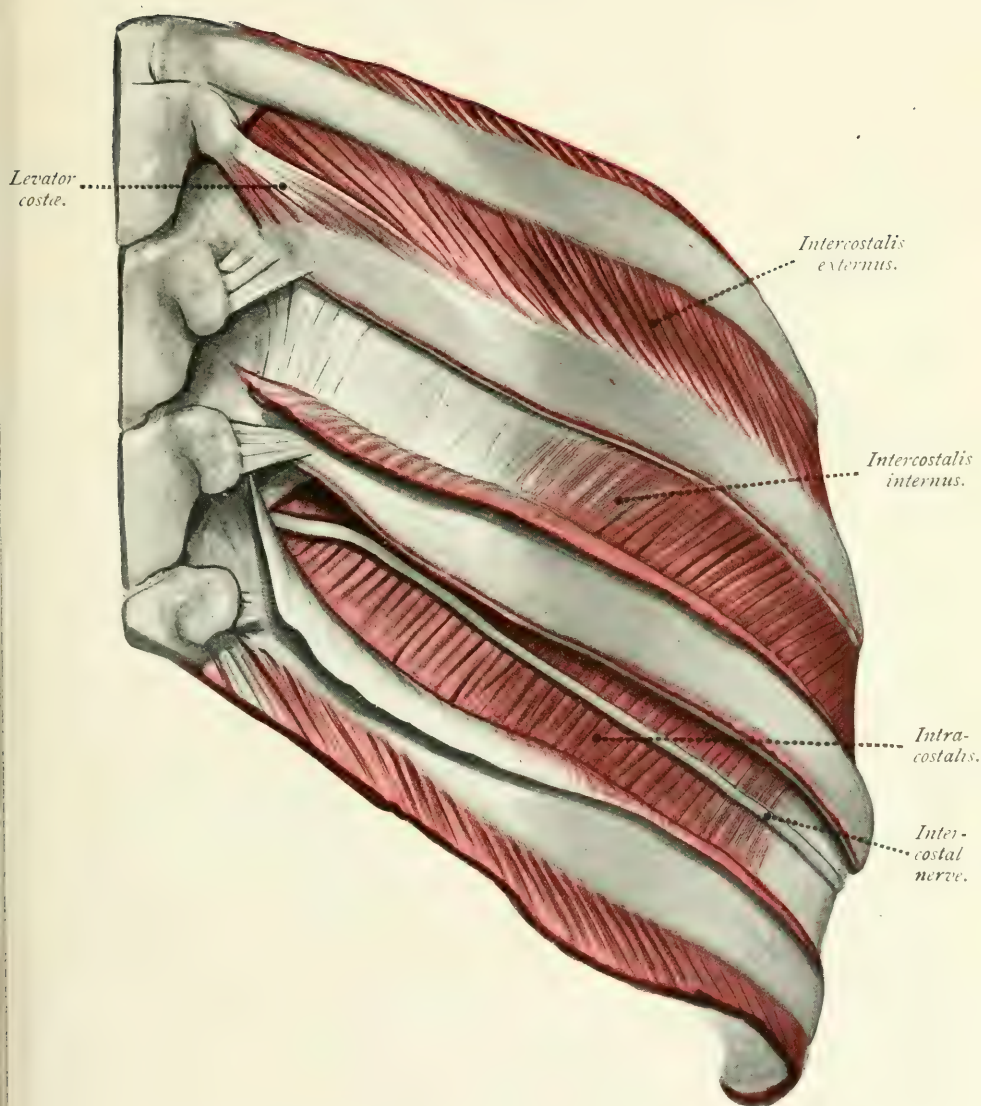


FIG. 63.—DISSECTION OF THE INTERCOSTAL MUSCLES OF THREE SPACES FROM BEHIND. (Walmsley.)

The Diaphragm

The diaphragm forms a musculo-tendinous partition between the abdominal and thoracic cavities, complete but for certain openings which transmit the structures passing from the thorax to the abdomen. Its muscular portion consists of fibres arching upwards from the circumference of the lower margin of the thorax, and from the front of the vertebral column, and converging upon the borders of a strong central aponeurosis, which forms the highest part of the structure. The tendinous centre is elongated from side to side, presenting a convex anterior and a concave posterior border, and is partially subdivided by indentations into lobes. It is surrounded on every side by the muscular portion, the fibres of which are directly continued by tendinous fibres into the aponeurosis.

According to its mode of development and to the arrangement of its fibres, the diaphragm is divided into a lumbar portion and a costo-sternal portion.

The *lumbar portion* arises from the upper lumbar vertebræ by two thick processes, the crura or pillars of the diaphragm, and from two fibrous arches on each side, lateral to the bodies of the vertebræ. The *crura* (figs. 64, 76, p. 223) arise by strong tendinous fibres, intimately connected with the anterior common ligament, from the upper lumbar vertebræ and the interposed discs. The right crus is usually stronger than the left, and descends further on the vertebral column. It reaches the third or fourth vertebra, while the left crus descends only to the first or second. The tendinous portions of the crura are continued higher medially than laterally, and curving forwards and medianwards join, as a rule, in the middle line, so as to form an arch over the front of the aorta. Inferiorly the medial margins of the two crura frequently meet behind the vessel, which is thus enclosed in a fibrous loop or ring. The muscular fibres of the crura spring from the tendons in thick bundles, and these, diverging slightly, pass upwards to the concave posterior margin of the central aponeurosis. The medial fibres of the two pillars, according to classical descriptions, do not go direct to the aponeurosis, but decussate in front of the aortic opening, and surround the œsophagus, so as to form an elongated aperture for its passage. In front of this opening they again cross to some extent, as they join the central tendon. In the first decussation the bundle from the right crus generally passes in front of that from the left. It is also the larger of the two, and the more constant. The left fasciculus is often wanting, in which case the œsophageal opening is altogether bounded by the crossed and uncrossed fibres of the right crus. According to Low and Eisler this is the normal arrangement, because it is found that the left bundle, even when present, after crossing dorsal to the other, diverges to the right before it reaches the margin of the opening. Normally, therefore, according to Low, the œsophageal opening is to be described as an elongated slit formed by the splitting of the medial fibres of the right crus. Each crus is pierced by the great splanchnic nerve, and it generally happens that the aperture is carried downwards as a cleft separating the crus, as described above, into a larger medial and a more slender lateral section. The remaining fibres of the lumbar portions of the diaphragm are connected with two fibrous bands known as the *arched ligaments*. The medial band (*arcus lumbo-costalis medialis*) extends from the body to the transverse process of the first lumbar vertebra, and sometimes also to that of the second, and arches over the upper part of the psoas muscle. The lateral band (*arcus lumbo-costalis lateralis*) extends from the transverse process of the first lumbar vertebra, and crosses over the front of the quadratus lumborum muscle. It is intimately connected with the fascia covering the muscle, and is considered

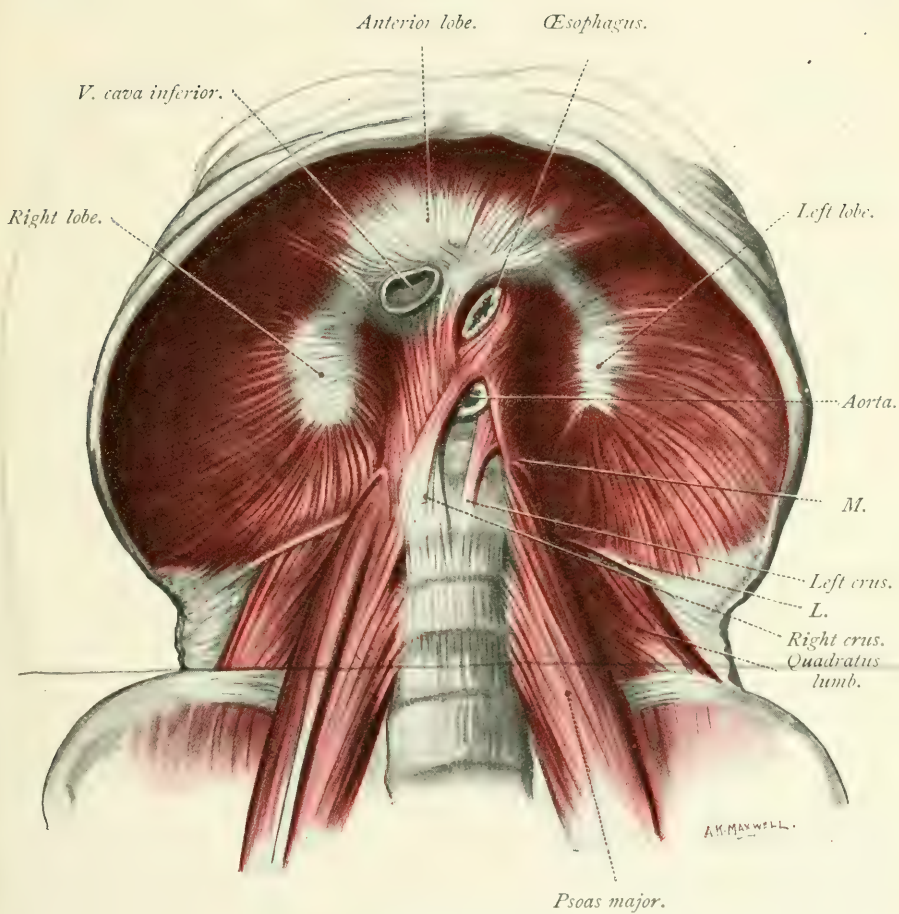


FIG. 64.—THE DIAPHRAGM FROM BELOW.

M, medial arched ligament; *L*, lateral arched ligament.

by some anatomists as a thickening of this fascia. It seems more probable that it corresponds, joining as it does the costal process of the first lumbar vertebra with the last rib, to less well marked fibrous arches, which join the extremities of the tenth and eleventh and eleventh and twelfth ribs, and also give attachment to muscle fibres. From both arched bands fleshy fibres take origin, and are directed upwards to the lateral portion of the posterior margin of the tendinous centre. It frequently happens that the fibres spring only from the medial portion of the lateral arch, and in that case a triangular interval (*trigonum lumbo-costale*) is left between the lumbar and costal parts of the muscle.

Through the gap thus formed the areolar tissue of the thoracic cavity is continuous with that of the abdomen. In the defect known as congenital diaphragmatic hernia, it is widely patent and the abdominal viscera extend through it into the thoracic cavity.

The costo-sternal part of the diaphragm is described in two parts according as the fibres arise from the ribs or sternum (fig. 65). The *costal portion* consists of a series of serrated slips arising from the cartilages of the six lower ribs, and interdigitating with the attachments of the transversus abdominis muscle. The attachments extend in the case of the four lower ribs to the ends of the bony ribs on their outer aspect. In the intervals between the tenth and eleventh and eleventh and twelfth ribs, tendinous arches springing from rib to rib also give origin to muscular fibres. There is sometimes a direct continuity with the fibres of the transversus muscle below the last three ribs. The *sternal portion* consists of two narrow slips which arise from the back of the metasternum near its extremity. They are often united with one another in the middle line so that the sternal origin appears unpaired. On each side between the sternal and costal portions there is an interval which gives passage to the epigastric division of the internal mammary artery, and some lymph vessels.

The muscular fibres are shortest where they spring from the sternum. From this point lateralwards the costal fasciculi increase in length to the level of the eighth or ninth rib, and then shorten again by degrees as they arise from the shorter hinder ribs.

The **central tendon** (fig. 64) may be described as having three lobes, an anterior and two lateral, which radiate outwards from a central area. The anterior lobe is roughly triangular with blunted apex and sides slightly curved. The lateral lobes are rather tongue-shaped, passing obliquely backwards and lateralwards on either side. The long axis of each is slightly curved with a medial concavity, and the left is distinctly narrower than the right. The central area shows posteriorly a thick node of tendinous bundles intercrossing with one another. To the right of this where right lobe and central area join, there is a large opening by which the vena cava inferior enters the pericardial cavity. On the whole convex towards the chest cavity the central tendon is somewhat depressed where it underlies the heart, but is prominent on each side. The right cupola rises to a higher level than the left. The aponeurosis is composed of tendinous bundles connected with the muscular fibres, and interwoven with one another in complex fashion.

The central tendon is made up of a multitude of fibres running singly, or applied to each other in sheets or flat bundles of varying width, the whole forming a compactly interwoven tendinous sheet (fig. 66). The pattern of the weaving, which is remarkably constant, is simpler and more homogeneous throughout each of the three lobes, but is rendered more complex in the central intermediate region by a system of bands binding together the more peripheral parts. Both surfaces of the tendon are clothed with a distinct fascial layer; below, this is more delicate and strips off easily; above, it is denser, more adherent and firmly attached to the pericardium, which is not structurally attached to the central tendon itself except at the apex of the anterior lobe. The *anterior lobe* is closely woven of fibres arising from the muscle at the margins and

running backwards to the central region in gentle curves, convex forwards, decussating near the middle line of the lobe. Occasional scattered transverse fibres also occur on the upper surface or towards the apex. The *right and left lateral lobes* are each mainly formed of a sheet of fibres passing transversely to the long axis of the lobe, and running into obvious continuity with the muscle fibres on each side; decussation in the axial line, if any, is confined to the tip posteriorly. These transverse fibres are mainly on the under aspect of the lobes, but on the upper surface the sheet is strengthened by a layer of finer fibres running longitudinally. These curve in towards

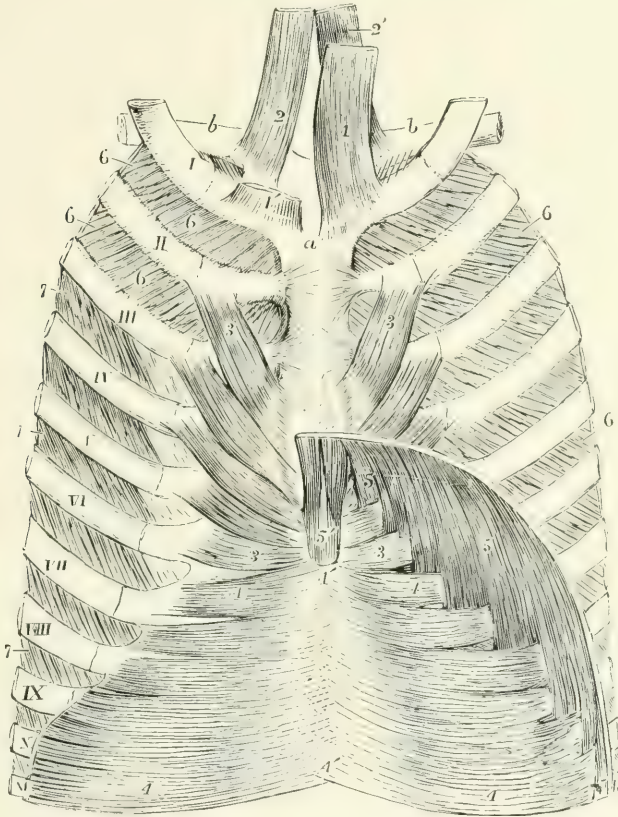


FIG. 65.—DEEP MUSCLES OF THE ANTERIOR WALL OF THE THORAX, SEEN FROM BEHIND. (Allen Thomson, after Luschka.) $\frac{1}{2}$

a, back of presternum; *b, b*, clavicles; I to XI, anterior parts of eleven ribs and costal cartilages; 1, 1', sterno-thyroid muscles, that of the left side being cut short to show more fully the next muscle; 2, 2', sterno-hyoids; 3, 3, triangularis sterni; 4, 4, upper part of transversus abdominis, the right and left muscles meeting at 4', 4', the back of the linea alba; 5, 5, attachments of diaphragm to the lower ribs (the twelfth not represented in the figure), interdigitating with those of the transversus; 5', the two slips to the metasternum; 6, 6, 6, internal intercostal muscles extending to the sternum, shown in all the spaces on the right side, but only in the highest two of the left side; 7, 7, 7, in the lower spaces of the left side, the external intercostal muscles are seen, the internal having been removed.

the centre posteriorly so as to form a felted decussation. This extends over the muscular part, forming a meshwork becoming finer and opener towards the periphery, so that the tendon is not so sharply marked off from the muscular part on the thoracic as it is on the abdominal aspect. Anteriorly the antero-posterior fibres diverge towards the margins of the neck of the lobe, thus exposing on the upper surface the anterior part of the transverse sheet. The right lobe shows in addition an incomplete third layer, in the form of a longitudinal band on the inferior surface which broadens behind, but narrows in front into a ribbon-like band sweeping round the lateral side of the vena caval opening. On either side of this the main transverse sheet is exposed, and

between this and the narrow part of the longitudinal ribbon the right inferior phrenic vessels pass. In the *central zone* four well-marked bands of fibres appear radiating diagonally from a central decussation like the bars of a St Andrew's Cross. The decussation appears as a node of compressed tendinous strands, situated in front of the œsophageal opening and to the left of the vena caval orifice. Through this the fibres run mainly in two diagonal streams, but others are confined to the same side, and run into adjacent bands, so that the arrangement resembles that of the nerve fibres in the optic chiasma. As for the bands themselves the posterior pair run back along the inner margins of the corresponding posterior lobes; some fibres curve across the neck of the lobe and so fall into line with the layer of transverse fibres, while others run into continuity with the medial half of the superior longitudinal layer, the lateral fibres of which join the muscle fibres on the same side where anterior and posterior lobes join. The anterior bands radiate widely, to become continuous with the more lateral fibres of the anterior lobe and with the muscle fibres on its margin, on the same side, and at the point where anterior and posterior lobes join. In addition the right anterior band sends a strong stream of fibres backwards round the vena caval opening into continuity with the inferior longitudinal layer of the right lobe, the remaining fibres of which join the muscle fibres antero-lateral to the caval orifice. This orifice lies in the angle between the right anterior and posterior radiations, which overlap to close off the foramen laterally,

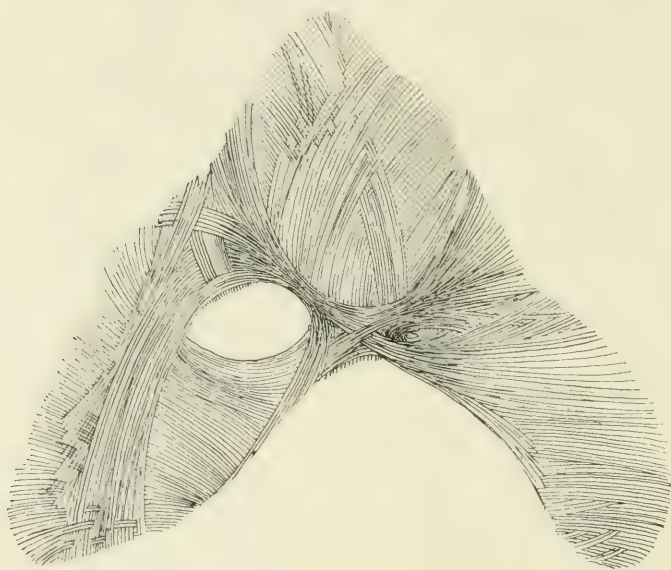


FIG. 66.—CENTRAL APONEUROSIS OF DIAPHRAGM FROM THE UNDER ASPECT, TO SHOW THE ARRANGEMENT OF THE TENDINOUS FIBRES. (For description, see text.)

the overlapping being strengthened and rather obscured by an accession of fibres from the coats of the vein to the margin of the tendon. Between the radiating bands on the left side is a thinner portion of the aponeurosis floored by a single layer of fibres blended with the borders of the adjacent bands, and often showing a minute perforation for a vein. The more central fibres of the anterior lobe, and those from the crura, join the node in front and behind. The importance of this description, which is founded on work done in the author's laboratory by Dr D. M. Blair, is that it represents the tendon as bilaterally symmetrical. The small aperture on the left side corresponds with the caval opening on the right side, and the small vein which passes through it is the remnant of the left vitelline vein of the early embryo.

Foramina.—There are in the diaphragm three large perforations for the passage respectively of the aorta, the œsophagus, and the vena cava, besides some smaller holes or fissures which are less regular: (a) The foramen for the aorta (*hiatus aorticus*), placed in front of the first lumbar vertebra, is bounded by tendinous fibres of the crura as already described. Besides the aorta, this opening transmits the thoracic duct, and generally also the large azygos vein. (b) The foramen for the œsophagus is opposite the tenth dorsal vertebra, and lies further forward than, as well as a little to the left of, the aortic opening, from which it is separated by the decussating fibres of the crura. It is oval in form, and is generally entirely surrounded by muscular fibres; in some rare cases, however, a small part in front is formed by the margin of the central tendon. Through

it pass also the vagus nerves and œsophageal branches of the coronary (left gastric) artery. Its margin is connected to the structures which pass through only by loose areolar tissue. (c) The opening for the vena cava (*foramen quadratum*) is placed in the highest part of the diaphragm about the level of the disc between the eighth and ninth dorsal vertebræ, in the tendinous centre at the junction of the right lobe and the central area posteriorly. Its form is somewhat quadrangular; and it is bounded by fasciculi of tendinous fibres which are firmly attached to the wall of the vessel. Besides the foregoing large foramina there are small perforations through the crura for the splanchnic nerves on both sides, and for the small azygos vein on the left side, while the large azygos vein often takes its course through the right crus. The cord of the sympathetic nerve either perforates the outer part of the crus or passes under the medial arched ligament; and the last dorsal nerve descends on the quadratus lumborum beneath the lateral arched ligament. Round the margins of the central tendon, on the under aspect, branches of the inferior phrenic vessels often appear to pierce the diaphragm as they course peripheralwards. This is due to the fact that detached bundles of antero-posterior fibres arch over and hold down the vessels.

Form and Relations.—The upper or thoracic surface of the diaphragm is highly arched. Its posterior and lateral fibres, ascending from their connexion with the lower margin of the thorax, are for a considerable extent placed close to the ribs, the lungs, especially in their collapsed condition, not descending so far as the attachments of the diaphragm. Its thoracic surface is covered by the pleura and the pericardium. The pleura does not descend quite to the attachments of the costal slips, and a small interval filled with loose tissue is left between them. The fibrous layer of the pericardium is bound by fibrous tissue to the middle lobe of the central tendon and to the fascia covering the muscle substance in front of this, to a small extent to the right and a larger extent on the left of the middle line. The abdominal surface, of a deeply concave form, is lined, except for a small area posteriorly, by the peritoneum, and has in apposition with it the liver, stomach, the pancreas and spleen, kidneys and suprarenal bodies.

The central tendon where it underlies the heart is placed about the level of the meso-metasternal junction. The right cupola rises about the breadth of an intercostal space higher than the left, but the level of the diaphragm varies in different individuals and at different ages and in the two sexes. It rises to a higher level in young persons and in women, and sinks as life advances. But there is a considerable amount of variation. In the dead body it rises on the right side to the level of the junction of the fifth rib cartilage with the sternum, on the left side only as high as the sixth. In the living individual it stands higher, but the level varies with the phase of the respiratory rhythm.

Nerve Supply.—The diaphragm is supplied with motor nerve fibres entirely by the two phrenic nerves from the fourth and fifth cervical trunks. Filaments are in some cases contributed from the third or from the sixth cervical, and in rare instances from the second and seventh trunks. Each phrenic nerve divides as it enters the diaphragm into a dorsal and two ventral branches. The dorsal branch is distributed to the lumbar portion; the ventral branches are distributed with the two main branches of the inferior phrenic artery and supply the sternal and costal portions respectively. Both sets of branches are joined together in extramuscular and intramuscular plexuses, but there is no connexion between the two sets of plexuses.

Variations.—The sternal portion may be absent, and the costal origins extend to the sixth or even (Le Double) to the fifth rib. The slip from the twelfth rib may be absent, and if this be associated with an absence of the fibres from the lateral arched band, the trigonum lombo-costalis becomes an extensive gap. This condition in exaggerated form occurs in congenital diaphragmatic hernia. In such cases it must be noted that the lumbar portion of the diaphragm extends antero-posteriorly on the medial side of the aperture. The extension of muscle fibres on to the fascia of the psoas or quadratus lumborum occasionally occurs. Connexions with the transversus abdominis muscle have already been mentioned. Various detached or aberrant bundles of muscle fibres have been described. Some of these are very unusual, and the following only need be referred to here: (a) From the right crus in the majority of bodies, a slip extends in the so-called *suspensory ligament of Treitz* to the back of the duodenum near the duodeno-jejunal junction with an extension to the mesentery along the vessels. (b) From the medial borders of the crura, a band of connective tissue containing muscle fibres is continued on to the surface of the œsophagus. According to Le Double this occurs in the majority of cases examined for its presence. (c) Not infrequently detached bundles of muscle fibres are observed in the tendinous centre, either running on the surface or between the layers of the aponeurosis.

The muscular tissue of the diaphragm is derived in the human embryo from a premuscle mass laid down in the cervical region in continuity with that which gives origin to the infrahyoid group of muscles. The rudiment is bilateral, and has no observed connexion with the cervical myotomes, but from the nerve supply it may be concluded that the formative material is related to the fourth and fifth cervical segments. The nascent muscular tissue enters the septum transversum (see Vol. I., p. 238) while it is yet situated in the region of the fifth segment and is accompanied by

filaments from the phrenic nerve. As the septum transversum becomes displaced backwards, the musculature and the nerves are carried with it. The two rudiments then unite to form a single mass, and in this, it is stated, the muscle tissue is best developed dorsally in the neighbourhood of the vena cava and œsophagus. The ventral portion spreads out to find attachment to ribs and sternum, while the dorsal mass appears to extend dorsalwards round the œsophagus in the mediastinal septum to become secondarily attached to the vertebral column. The last stage involves the spread of part of the muscle lateralwards, associated with the formation of the arched ligaments and the final closure of the trigonum lombo-costalis. The extent of this lateral spreading of the muscle varies. When it stops short of the lateral arched ligament, a distinct gap is left between the dorsal, or lumbar portion, and the costal. The passage between thorax and abdomen which is present in a case of congenital diaphragmatic hernia represents a patent pleuro-peritoneal opening (Keith).

Action of Muscles of Respiration.—Respiration involves two acts or phases, viz. inspiration and expiration, in which air is successively drawn into the lungs and expelled from them by the alternate increase and diminution of the chest cavity. The muscles primarily concerned in these changes in the capacity of the thorax are the costal muscles and the diaphragm. The costal muscles effect alterations in the transverse and antero-posterior diameters of the cavity by the movements of the ribs, and the displacements of the sternum which accompany these movements (see Vol. IV., Part I., p. 232). By the alternate contraction and relaxation of the diaphragm the floor of the thorax is depressed or elevated and the vertical height of the cavity is correspondingly altered. The costal muscles and the diaphragm are in themselves sufficient to effect the movements necessary for ordinary respiration, but in deep, and still more in forced breathing, many other muscles come into action with the object of still further expanding the chest cavity; indeed in circumstances of great urgency nearly every muscular system in the body is brought into service to facilitate directly or indirectly the efforts at respiration. It may be observed at this point that movements of the vertebral column are important factors in breathing, for when the column is bent forwards the ribs are pressed together in the concavity of the curve, and conversely when the column is extended the ribs are separated.

Before considering the action of the muscles of respiration one or two preliminary points must be mentioned. It follows from the mechanism of the ribs and their cartilages that the chest wall is under elastic strain. It was demonstrated by Landerer, and since confirmed by Fick and others, that the elastic force of the cartilages and ribs in itself tends to raise the ribs towards the position of inspiration, and that this tendency is counterbalanced by the attachment of the abdominal wall to the thorax, and in the erect position, standing or sitting, by gravity, that is by the weight of the attached abdomen. The tonic contraction of the muscles of the abdomen will of itself oppose the rise of the ribs. Between these two forces the chest wall is brought, irrespective of muscular action, into a position of equipoise. This position may be called the position of rest in the respiratory cycle, being that in which we feel the least strain when breathing is arrested. Inspiration and expiration involve alternate movements in opposite directions from this position of natural equipoise. Again it is to be noted that the outward movement of the ribs diminishes from the long false ribs upwards, and that the first rib is the most fixed member of the series, by reason of its ligamentous attachment to the clavicle, the articulation of that bone to the pre-sternum, the attachment of the scalene muscles above, and the strain of the intercostal muscles and ribs below.

Intercostal Muscles.—The inspiratory movement, *i.e.* the elevation of the ribs by which larger costal arches are brought to the level occupied in the position of rest by smaller arches, is effected by the external intercostals, and the interchondral portions of the internal intercostal muscles, possibly by the whole of the internal intercostal muscles as defined in this work. The expiratory movement is brought about by the transversus thoracis (under which term are included in our description of the chest muscles the intracostales, the subcostales, and the triangularis sterni muscles) and the transversus abdominis.

The doctrine here laid down in regard to the action of the intercostal muscles is associated with the names of Hamberger and Hutchinson, and is now fairly generally accepted. The manner in which these muscles act has been a matter of controversy from an early period. The difference of opinion has concerned mainly the action of the internal muscles. Haller (1708-1777) maintained that they had the same action as the external intercostals, and were elevators of the ribs, while Hamberger (1697-1755) considered that they acted as depressors. Hutchinson held that the interchondral parts of the muscles elevated, while the lateral parts depressed the ribs, and the debate has centred on this point ever since.

The difference in function between the anterior and posterior parts of the internal intercostal muscles of classical descriptions is very probably the reason for the anatomical features of the two deeper intercostal layers which have been named in the descriptive account above—the internal intercostal and intracostal muscles.

Both inspiration and expiration thus involve muscular action, but both movements are inaugurated, and the work is lessened, by a purely mechanical factor, viz. the tendency of the chest wall to take up, under the competing strains to which it is subjected, a position of natural equipoise.

The abdominal muscles act as antagonists to the elevators of the ribs, while the scalene muscles, the sterno-mastoids, and the extensors of the spine are fixation muscles. In ordinary respiration only the lower ribs move, but in deep breathing all the ribs are elevated, and other muscles come into action. The scaleni now acting as synergists raise the first two ribs, the sterno-mastoids and infrahyoid muscles raise the presternum and clavicles, while the extensors of the spine extend the thoracic part of the column, and thus indirectly elevate the ribs. A deeper breath brings the elevators of the shoulders into operation, partly to relieve the chest of the weight of the arms, but more particularly to raise and carry back the scapulæ and fix them in that position. The pectoralis minor and subclavius muscles taking their fixed points from the shoulder girdle, now bring their pull to bear on the ribs to which they are attached. In still more forced respiration the vertebral column is strongly extended and the head is thrown back in aid of the neck muscles, while the humeri are fixed so that the greater pectoral muscles and costal portions of the latissimus dorsi muscles, reversing their ordinary mode of action, may forcibly expand the chest. In ordinary respiration the transversus thoracis and the transversus abdominis muscles are the expiratory agents, but in deep and forcible expiration the whole of the abdominal wall is powerfully contracted, while the quadratus lumborum and ilio-costalis muscles also come into operation.

The *levator costarum* muscles appear, in spite of their title, to have little influence in raising the ribs. They are chiefly concerned in extension and lateral rotation of the vertebral column. According to Fick the upper six pairs of muscles have a slight power of elevating the ribs to which they are attached. The same is probably true of the *serratus posterior superior* muscle.

The *diaphragm* performs its respiratory function in virtue of the descent which accompanies the contraction of its muscular portion. The absolute range of movement, however, between deep inspiration and deep expiration is not great, being in the male only 34 mm. on the right and 32 mm. on the left side (Halls Dally). In ordinary breathing the movement is not more than about 15 mm. Fick suggests that the descent of the diaphragm has relatively little effect in actually enlarging the capacity of the thoracic cavity, and that its contraction in inspiration coincidently with the intercostal muscles has rather the effect, by preventing its being drawn into the thorax, of maintaining the gain in capacity produced by the rib movements. The central aponeurosis is drawn down by the crural fibres, and its descent is necessarily accompanied by traction on the pericardium and through it on the heart and great vessels. The descent and stretching of the aponeurosis being timed with the establishment of a negative pressure in the thorax, and a raised pressure in the abdomen, must obviously favour the return of blood to the heart through the inferior vena cava.

One of the important parts the diaphragm has to play is to regulate the pressure in the chest cavity and by opposing the abdominal muscles to control the output of air through the glottis, as in speaking and more especially in singing. Its direct antagonists are the transverse muscles of the abdomen, while the serratus posterior inferior and quadratus lumborum muscles are fixation muscles against the pull of its lateral and posterior costal fasciculi. In normal breathing the action of the diaphragm is associated with the upward, outward, and backward movement of the lower ribs. This is what is known as *abdominal respiration* as distinguished from *costal respiration* in which the upper ribs are utilised. The movement of the ribs is more pronounced in the recumbent posture, and it has always been supposed that women utilise their ribs more than men. It is doubtful whether this is a true sex character; it is probably only a habit induced in some women adventitiously, although of course in pregnancy costal breathing must necessarily be resorted to. It is possible by practice to eliminate the costal movements and breathe by the diaphragm exclusively.

The Muscles of the Abdominal Wall

The primary function of the muscles of the wall of the abdomen is to exert a compressing force on the contents of the cavity. Accordingly we find in the flanks three superimposed sheets of muscle which fill up the space between ribs and pelvis, and obtain their *point d'appui* from these bony parts, as well as from the vertebral column behind. Each sheet ends over the front of the abdomen in a broad aponeurosis, the fibres of which are continued to the median plane where they form, by decussating with one another, a raphe known as the *linea alba*. On each side of this the aponeuroses are united with one another inseparably to

form a sheath for the rectus abdominis muscle which extends in a vertical direction from pelvis to thorax.

M. Obliquus Externus (fig. 44, p. 100).—The external oblique muscle, the strongest and most superficial of the three broad muscles of the abdomen, arises from the eight lower ribs, by slips arranged in a serrated and overlapping series, four or five of them interdigitating with origins of the serratus anterior, and three or four with origins of the latissimus dorsi. The lower and upper digitations of the muscle are connected with the ribs near their cartilages; the intermediate ones are attached to the outer surfaces of the ribs at some distance from their extremities; the lowest slip generally embraces the cartilage of the last rib. The fleshy fibres from the last two ribs pass down in a nearly vertical direction to be inserted into the external margin of the iliac crest for about the anterior half of its length. All the rest of the fasciculi incline downwards and forwards, and ending in tendinous fibres form the broad aponeurosis by which the greater part of the muscle is inserted.

The **aponeurosis** of the external oblique is wider below than above, and is more extensive than that of either of the subjacent broad muscles. The line of origin falls along a vertical line from about the tenth costal cartilage to a short distance in front of, and above the anterior superior iliac spine, at which point it turns sharply lateralwards to the iliac crest behind the spine. It extends from the metasternum to the symphysis pubis, and here, inseparably united with the underlying aponeurosis, it forms the anterior lamella of the sheath of the rectus. Its upper part is connected with the pectoralis major, giving origin to the lowest fasciculi of that muscle.

The constituent fibres of the aponeurosis for the most part continue the direction of the muscular fasciculi and extend to the median plane, where they meet and intercross with those of the muscle of the opposite side in the linea alba. The decussation extends down to the pubic bone, and just above this the crossing fibres are disposed in two layers, superficial and deep. The deep layer crosses in front of the rectus, and is attached to the ilio-pectineal line of the opposite side alongside the ligament of Gimbernat (lacunar ligament), some of the fibres of the latter being continued into it. This is the *triangular fascia* or *reflex ligament of Colles* (fig. 69, p. 201). The lowest fibres of the aponeurosis are closely aggregated together, and extend from the anterior superior iliac spine to the pubic spine in the form of a thickened band which is called the inguinal ligament of Poupart. The inguinal ligament is blended along its whole length with the fascia lata of the thigh, and in consequence of this connexion it is curved with its convexity downwards. The curvature is more pronounced in the medial two-thirds of the band, but the degree of curvature and the tension of the ligament vary with the position of the limb, being increased in extension and eversion, and diminished in flexion and inversion of the thigh. The ligament is not only bound to the fascia lata, but in its outer third it is attached by its deep aspect to the fascia iliaca, descending on the ilio-psoas muscle as well as to the fascia transversalis. From the point where it becomes free from the iliac fascia it arches over the femoral vessels as they enter the thigh. The tendinous bundles of this portion of the band turn obliquely inwards and form a grooved surface on which the spermatic cord or round ligament rests. The major part of the bundles are attached to the pubic spine, but the deeply placed and inflected fibres are fixed to the medial part of the ilio-pectineal line for a distance of about 2 cm., constituting a triangular layer which is known as Gimbernat's ligament (lacunar ligament) (figs. 69, 70). This triangular band presents supero-medial and infero-lateral surfaces, and a concave lateral margin which bounds the femoral ring on the medial side.

The aponeurosis is perforated by numerous small apertures for the passage of cutaneous vessels and nerves, and near the body of the pubic bone by one large opening, through which the spermatic cord in the male, or the round ligament in the female, leaves the abdominal cavity. This is known as the *superficial inguinal ring* (figs. 69, 70), and is formed by the separation of the fibres passing to the linea alba and anterior part of the pubic symphysis from those joining the medial part of the inguinal ligament and attached to the pubic spine. The direction of the opening is obliquely upwards and lateralwards conformably to the direction of the principal fibres of the aponeurosis. The base of the ring is formed by the pubic crest, and its sides by the two sets of diverging fibres called the pillars or crura. The upper or medial pillar is flat and straight, and is attached to the anterior aspect of the pubic bone, decussating with the corresponding fibres of the opposite side. The lower or lateral pillar is in its upper part flat and thin, but its lower part, which is formed by the pubic end of the inguinal ligament, is thick and prismatic and curves strongly inwards to its insertion at the pubic spine. On the surface of the aponeurosis, especially in its lower part, are seen slender bundles of fibres crossing transversely and binding together its principal oblique fibres. These are most developed in the neighbourhood of the outer third of the inguinal ligament, whence they arch forwards and then with an upward inclination. They extend across the upper part of the superficial inguinal ring, closing to a greater or less extent the irregular interval left between the diverging pillars, and hence have received the name of intercolumnar (intercrural) fibres. From the proper fascia of the aponeurosis, to which these fibres seem to belong, a thin membrane is prolonged downwards upon the spermatic cord, known as the *intercolumnar* or *external spermatic fascia*. The superficial inguinal ring thus acquires a somewhat oval form, and its size varies in proportion to the degree of development of the intercolumnar fibres. In the male the opening has an average length of about 25 to 27 mm., with a breadth of less than half of this. In the female it is usually much smaller.

Relations.—The external oblique is superficial with the exception of a small part at its posterior border which is overlapped by the latissimus dorsi. It lies upon the internal oblique and the lower ribs with their cartilages and the intervening intercostal muscles. The origins of the external oblique and latissimus sometimes meet at the iliac crest, but more frequently a small interval is left, and the free portion of bone forms the base of a triangular space between the two muscles, *triangle of Petit*, in which a hernia (lumbar hernia) has been seen to protrude.

Varieties.—The external oblique varies chiefly in the number of its attachments to the ribs. Absence of the highest and lowest digitation is not uncommon. On the other hand, one or more slips may be doubled, most frequently those from the eighth or ninth ribs, or an additional slip may arise from the lumbar fascia below the last rib. Besides the connexion with the pectoralis major, union, by tendinous intersection frequently, or by direct continuity rarely, takes place between the slips of origin of the external oblique and serratus magnus muscles. A similar connexion may exist between it and the latissimus dorsi or serratus posterior inferior. Instances have been recorded of the presence of deep accessory bundles arising from the ribs and separated by connective tissue from the main sheet. These slips arise from one or more of the lower ribs, and are attached independently at their other extremity to the iliac crest, anterior superior iliac spine, inguinal ligament, or sheath of the rectus. Detached slips arising, beneath the digitations from the fifth to the seventh ribs, from the fascia over the fifth or sixth intercostal space and ending in the upper part of the rectus sheath are figured by Eisler. A detached slip named *musculus saphenous* has been described, attached at both ends to the inguinal ligament and looping round the saphenous vein (Tyrie). The presence of a tendinous intersection in the muscle described by Le Double and Chudzinski is interesting in view of the segmented character of the muscle in lower forms, and the presence of regularly arranged tendinous intersections in many mammals. During the development of the muscle in the human embryo traces of segmentation remain where the muscle lies in direct contact with the external intercostals, but disappear later (Bardeen).

The external oblique is not confined, in many lower mammals, to the lower part of the thorax.

It extends forward to the first and second rib in some animals, *e.g.* in *Tarsius*, *Semnopithecus*, etc., among the lower primates. It may also reach backwards to the lumbar fascia. In the catarrhine apes the insertion of the muscle descends to the inferior iliac spine, and there is no inguinal ligament or Gimbernat's ligament in the same sense as in the human subject. The inguinal arch consists only of the unthickened edge of the aponeurosis.

M. Obliquus Internus Abdominis (fig. 67).—The internal oblique muscle, placed under cover of the external oblique, arises by fleshy fibres from the lateral half or two-thirds of the deep surface of the inguinal ligament; by short tendinous fibres from the middle lip of the iliac crest for two-thirds of its length; and by some fleshy fibres from the dorsal lamella of the lumbar fascia in the angle between the iliac crest and the erector spinæ muscle. From these attachments the fibres spread fan-wise over the side of the abdomen. The posterior fasciculi rise steeply upwards to be inserted by digitations into the lower margins of the extremities of the last three ribs. The attachment is mainly by fleshy fibres, placed in the same plane with, and running parallel to, the fibres of the internal intercostal muscles. The fibres from the anterior part of the iliac crest pass forwards and upwards, becoming more and more horizontal the nearer they approach the anterior iliac spine, to end in an aponeurosis on the front of the abdomen. The bundles from the inguinal ligament, sometimes detached from one another to a certain extent, and usually paler than the rest, incline downwards to the lower part of the aponeurosis, while the lowest fibres arching over the spermatic cord, or round ligament of the uterus, end with the lower fibres of the transverse muscle upon a deep lamella of the aponeurosis just above the pubic bone, as will be explained more fully below.

The **aponeurosis** of the internal oblique is less extensive than that of the external oblique. Its line of origin from the muscular belly runs from the end of the tenth costal cartilage downwards and medially towards the pubic bone; hence it is broader above than below. At the lateral border of the rectus, the aponeurosis splits into two layers, one passing before, the other behind the muscle. The two layers reunite in the linea alba, so that the rectus is enclosed in an aponeurotic sheath, the anterior layer of which is inseparably united, as already mentioned, with the aponeurosis of the external oblique, while the posterior layer is similarly blended with that of the transverse muscle. But this arrangement does not prevail throughout the whole length of the sheath. From the level of the eighth costal cartilage upwards the rectus lies directly on the thoracic wall, the upper border of the posterior layer of the sheath being attached to the margins of the seventh, eighth, and ninth rib cartilages and the metasternum. The anterior wall of the sheath over the upper part of the rectus is formed solely by the external oblique aponeurosis, the internal oblique making no contribution of tendinous bundles in this situation. The division of the aponeurosis into two layers ceases a little above half-way between the umbilicus and the pubic bone, and about on a level with the anterior superior iliac spine. From this point downwards the anterior wall of the sheath is formed by all three aponeuroses which, intimately united, pass wholly in front of the rectus. Owing to this arrangement the aponeurotic posterior wall of the sheath ends abruptly, in a more or less well-defined margin, which is lunate in form, with its concavity directed downwards, and is known as the semilunar (semicircular) fold of Douglas. It is to be noticed that the line of junction of the aponeurosis of the external oblique with that of the internal oblique falls on the medial side of the lateral margin of the rectus, and gradually approaches nearer the median plane as it descends. In consequence of this, the anterior wall of the sheath above the pubic bone consists of two layers. The deeper of these is formed by the aponeuroses of the internal oblique and trans-

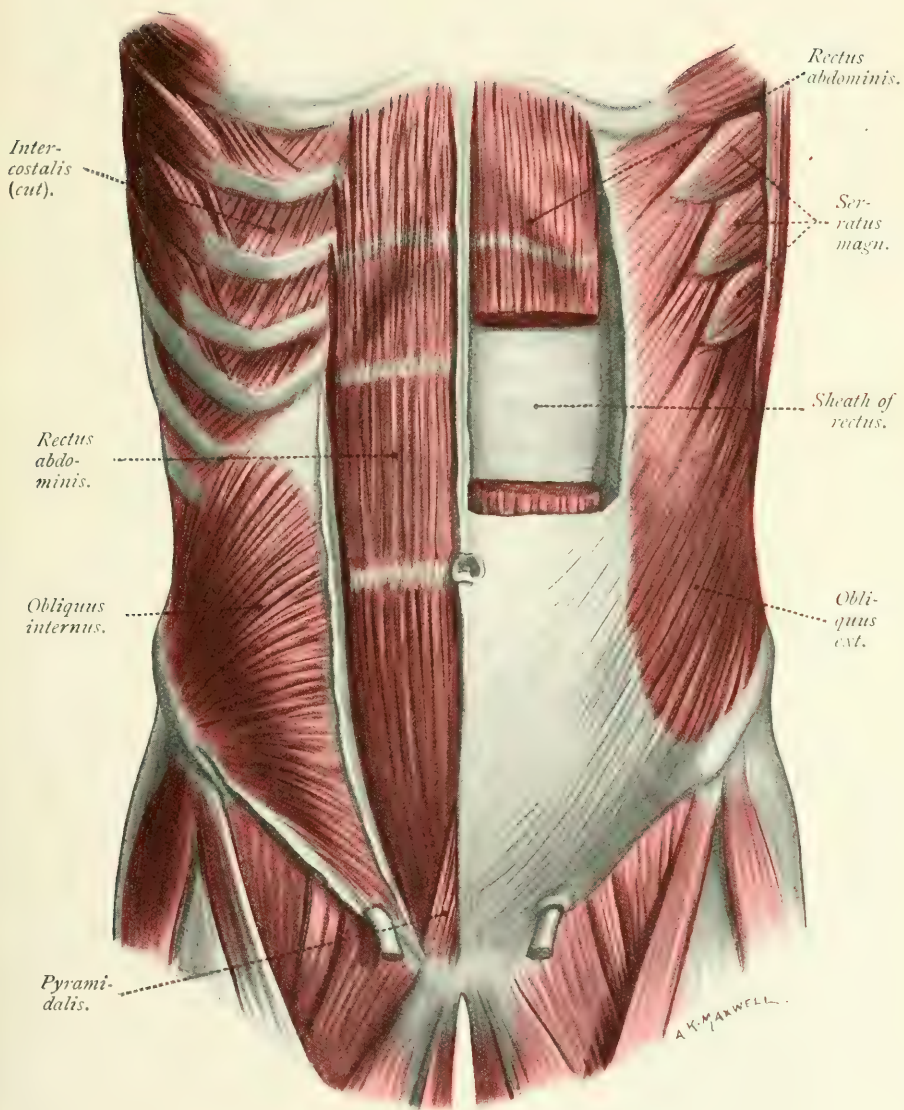


FIG. 67.—DISSECTION OF THE MUSCLES OF THE ABDOMINAL WALL. The obliquus externus has been removed on the right side and the sheath of the rectus has been opened. On the left side the rectus sheath has been opened and a portion of the muscle excised to show the posterior layer of the sheath.

versus which are intimately united, by interchange of fibres, along the margin of the rectus muscle. It is attached below to the pubic crest, and is prolonged on the ileo-pectineal line for a variable distance, in the majority of cases. This lateral extension may involve only the aponeurosis of the transversus, and it may be absent altogether. The lowest fibres of the internal oblique and transversus coming from the inguinal ligament are connected, when it exists, with this tendinous expansion, which has been known in this country as the *conjoined tendon* (*falx aponeurotica inguinalis*, B.N.A.) (see below, p. 205).

Relations.—The internal oblique muscle is almost entirely covered by the external oblique. The posterior part of the muscle arising from the lumbar fascia is under cover of the latissimus dorsi, and a small area of its surface is frequently exposed between the latissimus dorsi and the external oblique, when these muscles fail to meet at their iliac origins. At a higher level a triangular space is sometimes left if the serratus posterior inferior and the internal oblique do not meet. It is bounded by the erector spinae, the twelfth rib, and the border of the internal oblique. In this triangle (*trigonum lumbale superius*) the aponeurosis of the transverse muscle is exposed covered only by the latissimus dorsi muscle.

Varieties.—A fibrous band or inscription not infrequently interrupts the muscle opposite the tenth or eleventh rib. The inscription is prolonged forward from the end of the rib, and it occasionally encloses a slender cartilaginous slip, separate from that of the rib. In rare instances a similar inscription has been seen opposite the twelfth or even the eighth rib (Le Double). They represent, according to Eisler, tendinous intersections between the internal oblique and the internal intercostal muscles. An additional slip occasionally springs from the eighth costal cartilage. The portion of the muscle arising from the inguinal ligament may be separated by an interval from that springing from the iliac crest. Absence of the inguinal portion or of the anterior superior part of the muscle has been recorded. Fusion of the lower part of the muscle with the transversus may occur. In one case Le Double has recorded the presence of a deep slip which found insertion on the transverse process of the second lumbar vertebrae.

M. Cremaster.—This muscle exists as a separate system of fasciculi only in the male. It is best described as consisting of medial and lateral fasciculi. The latter are the stronger and often the only part of the muscle present. The fasciculi arise from the inguinal ligament medial to the internal oblique. They are sometimes placed in series with the fibres of this muscle, but in other instances are closely connected with the transversus muscle. The fasciculi surround the cord on its lateral aspect and emerge with it from the abdominal ring. The superior fibres turning inwards join the medial bundles and form loops over the cord which become successively longer towards the testicle. The remaining fibres spread out in the fascia and are attached to the tunica vaginalis of the testicle. The fasciculi of the medial part descend from the pubic spine on the medial and dorsal aspects of the cord. They spread out and interlace with those of the lateral part and end below on the tunica vaginalis.

Eisler holds that the peripheral fibres do not form continuous loops, although the medial and lateral fasciculi interdigitate with one another by tendinous intersections. In many cases continuity of the cremaster with the internal oblique can be determined by dissection, but in other cases the connexion with the transversus is a close one, and this may perhaps account for the divergence of view among authorities as to the origin of the muscle.

In the female a few fibres descending on the round ligament of the uterus correspond to the lateral fasciculi of the male cremaster.

M. Transversus (Transversalis) Abdominis (fig. 46, p. 105).—The transverse muscle subjacent to the internal oblique arises (1) from the inner surfaces of the cartilages of the six lower ribs by fleshy slips which interdigitate with the costal attachments of the diaphragm; (2) from the transverse processes of the lumbar vertebrae by a strong posterior aponeurosis; (3) from the inner margin of the iliac crest in the anterior two-thirds of its extent; (4) from the outer third,

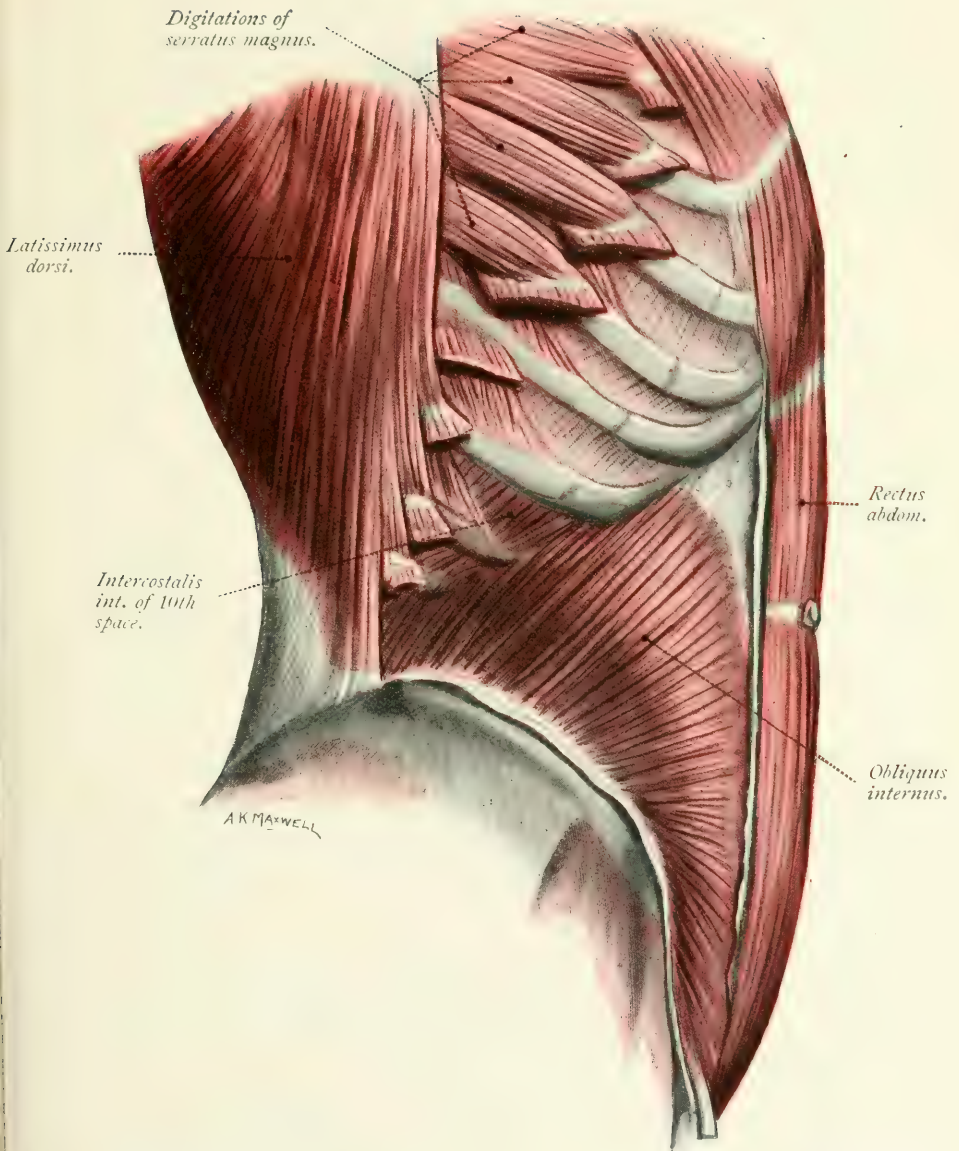


FIG. 68.—DISSECTION OF THE MUSCLES OF THE SIDE OF THE TRUNK. The external oblique muscle has been removed to show the internal oblique, but its digitations from the ribs have been preserved. The sheath of the rectus has been opened and its anterior lamella removed.

or outer fourth, of the inguinal ligament. The muscular belly is thinner than that of the oblique muscles; the fibres have for the most part a horizontal direction and extend forwards to end in a broad aponeurosis in front. The lowest fibres curve downwards, like those of the internal oblique, with which they are closely united and interwoven, to end on the conjoined tendon described above.

The *anterior aponeurosis* is broadest at the level of the umbilicus. Above this the muscular fibres extend gradually nearer the middle line behind the rectus muscle and the posterior lamella of the aponeurosis of the internal oblique, so that the tendinous sheet becomes progressively narrower until it ends in a pointed extremity on the metasternum. It is closely united with the hinder layer of the internal oblique aponeurosis, the line of junction following an oblique line from the metasternum to the lateral border of the rectus a little above the umbilicus. In the lower part of its extent the aponeurosis narrows again, its line of origin following the border of the rectus, where it becomes closely united with the posterior layer of the internal oblique aponeurosis by an interweaving of the tendinous fibres of the two sheets. The tendinous bundles accompany the posterior lamella of the internal oblique above, but below the point where the division of that layer ceases, they pass, like those of the internal oblique, into the anterior wall of the sheath of the rectus.

The *posterior aponeurosis* of the transversus is a tendinous sheet which extends from the last rib to the ilio-lumbar ligament and the adjoining part of the iliac crest, and intervenes between the erector spinæ and quadratus lumborum muscles. It is fixed to the tips of the transverse processes of the vertebræ by fibrous bundles, strengthened by radiating fibres from each point of attachment. The radiating systems of fibres from the two upper lumbar transverse processes extend to the last rib, forming what is known as the *lumbo-costal ligament*. The superficial lumbo-sacral aponeurosis is closely connected with the transverse aponeurosis, round the edge of the erector spinæ, and contributes fibres to it. The posterior aponeurosis constitutes the *middle layer of the lumbar fascia*, and is connected, at the margin of the quadratus lumborum, with the fascia on the anterior face of that muscle.

Relations.—Between the outer surface of the transverse muscle and the internal oblique are placed the lower intercostal nerves and a branch of the circumflex iliac artery. Its inner surface is lined throughout by the transversalis fascia which separates it from the subperitoneal tissue and the peritoneum. The muscle is continued superiorly into the triangularis sterni, or transverse muscle of the thorax.

Varieties.—The number of costal slips varies. It may be reduced to five or increased to seven. The muscle has been found fused with the internal oblique, and its absence has been observed. Failure of the inguinal bundles has been recorded; on the other hand, extension to the pubic spine has been noted, and the spermatic cord has been seen to pierce its lower border. Slender muscular slips are sometimes found between the rectus and the deep inguinal ring. They take several forms and have received various names.

M. rectus abdominis (figs. 67, 68) is a long flat muscle consisting of vertical fibres, and extending from the pubic bone to the level of the fifth rib. The medial border is separated from the muscle of the other side by a narrow interval and is applied to the linea alba along its whole length. The lateral border is somewhat convex below the level of the umbilicus, and inclines medialwards, so that the muscle becomes narrower inferiorly. The muscle is attached to the pubic bone by a flat tendon, consisting of two parts. The lateral portion is the larger, and is fixed to the pubic crest. The medial part descends lower, and is connected with the ligaments covering the front of the symphysis, becoming blended with the opposite tendon, by a decussation of their fibres in the middle

line. A certain number of thin fleshy fibres on the medial border of the muscle are generally found connected by tendinous fibres to the linea alba, above the pubic symphysis. The costal attachment of the muscle is effected by three distinct slips of unequal size, which are inserted into the cartilages of the fifth, sixth, and seventh ribs. The lateral slip is the broadest, and it usually extends on the fifth rib beyond the cartilage. Some fibres are also frequently found attached to the front of the metasternum.

The muscular belly is interrupted by three or more irregular tendinous intersections known as the *inscriptiones tendineae* (fig. 67). The three which are most constant are placed, one opposite the umbilicus, another opposite the lower end of the metasternum and the eighth costal cartilage, the third intermediate between the first two. These intersections usually extend across the whole or the greater part of the muscle. A fourth line is frequently present below the umbilicus, but is limited to the lateral part of the muscular belly, and the same is true for a fifth occasionally seen, the position of which is variable. The intersections do not usually penetrate the whole thickness of the muscle, but are confined chiefly to its anterior fibres, and are firmly fixed to the anterior wall of the sheath of the muscle, while the posterior surface of the muscle has no attachment to the sheath.

This division of the rectus by tendinous septa is not strictly metameric. According to the available developmental data, the original myotomic segmentation of the rectus column disappears, to be partially re-established later. Notwithstanding, the interruption of the muscular belly by septa, which is also seen in the corresponding musculature in the neck, is to be regarded as a vestige of the primitive segmented condition of the trunk muscles. The intersections may be increased to five or even to six, and cases of a reduction to two or even one have been noted.

Varieties.—The rectus muscle in lower mammals extends further over the thorax than in the human subject. In many of the lower primates it reaches the first rib and the clavicle. It may rise to the fourth or even the third rib in man, in certain very rare cases even higher. On the other hand, the slip attached to the fifth rib may be absent. The reduction of the rectus in man, as has been already indicated, is to be correlated with the greater extension of the limb musculature over the thorax.

M. Pyramidalis (fig. 67).—This small muscle rests on the lower end of the rectus, in the sheath of which it is contained. It arises by short tendinous fibres from the front of the pubic bone below the rectus, and, becoming narrower as it ascends, is inserted into the linea alba in the lower fourth of its extent. It is separated from the rectus by loose connective tissue, but sometimes an expansion from the conjoined aponeuroses of the internal oblique and transversus intervenes between them.

Varieties.—The muscle varies greatly in size, and is often absent on one or both sides, in which case the size of the lower part of the rectus is increased. It is rarely quite symmetrical on the two sides. It fails in about 16 per cent. of subjects, and is more frequently absent in the male, also more often on the right than on the left side. In some instances the muscle has been found doubled.

The muscle is well developed in the monotremes and marsupials and is attached to the epipubic bone which exists in the pouched mammals. In some orders of the mammalia it is absent, in others it is relatively more developed than it is in man.

The **linea alba** is a median raphe formed by the decussating fibres of the aponeuroses of the lateral muscles of the abdominal wall. It extends from the metasternum to the pubic bone, and is broader above than below. This difference is due to the fact that above the semilunar fold of Douglas the fibres forming the raphe do not all cross in one plane. The fibres of the anterior wall of the rectus sheath of one side pass obliquely into the posterior wall of the sheath of the other side and *vice versa*. Where the dorsal wall of the sheath comes to

an end, the decussation in the sagittal plane ceases, and the raphe is reduced to a narrow septum triangular in section. A little below its middle point the whole line widens out into a circular flat space in the centre of which is situated the cicatrix of the *umbilicus*. The cicatricial plug occupies a fibrous ring formed by the deflection of the decussating fibres. The great mass of the fibres are more or less transverse in direction, but at the lower end where the band becomes narrow a strand of longitudinal fibres is detached from it posteriorly. These are contributed mainly by the recti muscles and the medial horns of the semilunar folds, and constitute what are known as the *Adminiculum*¹ *lineæ albae* (fig. 69). It spreads out below into two small triangular expansions fixed on each side to the upper border of the pubic bone behind the outer head of the rectus, enclosing a fat-filled recess. At the upper end there are also a few longitudinal fibres descending from the metasternum. The linea alba is much increased in breadth when the abdomen is distended during pregnancy or from disease.

The **linea semilunaris** is a curved linear depression on each side of the front of the abdomen, situated along the outer border of the rectus muscle, and appearing as a white line on the surface of the aponeurosis of the external oblique. It corresponds to a narrow portion of the aponeurosis of the internal oblique, between its division to form the sheath of the rectus medially, and the termination of the fleshy fibres of the muscle laterally. The **lineæ transversæ** are cross lines, corresponding to, and produced by, the tendinous intersections of the rectus.

Nerves of the Abdominal Muscles.—The abdominal muscles are supplied by the lower intercostal nerves. In the case of the internal oblique and transversus, twigs from the first or first and second lumbar nerves are brought in the ilio-inguinal, ilio-hypogastric, and genito-femoral nerves. The nerves of supply from the intercostal trunks course in the abdominal wall between the internal oblique and transverse muscles. The filaments for the external oblique (from Th. 5 to Th. 12 (L. 1.) accompany the lateral cutaneous branches through the muscle and enter on its superficial aspect, forming a complicated plexus. The internal oblique receives its branches from the tenth, eleventh, and twelfth intercostal trunks, and from the ilio-inguinal and ilio-hypogastric nerves. These last bring filaments from the first lumbar nerve and reach the muscle on its deep aspect after they have pierced the transverse muscle. According to Eisler, branches are also given off from the genito-femoral nerve to the posterior part of the muscle, bringing filaments from the second lumbar nerve. The line of entrance of the twigs into the muscle runs from the eleventh rib to the superficial inguinal ring concentric to the origin of the muscle.

The transversus abdominis receives its supply from the intercostal nerves corresponding to its costal slips, also from the ilio-inguinal, ilio-hypogastric, and (according to Eisler) from the genito-femoral nerves, *i.e.* from the fifth or sixth thoracic to the second lumbar nerve. The line of entrance runs from the point of the ninth rib concentric to the linea semilunaris. The filaments thus enter the highest bundles near their origin, the middle about the middle of their length; the iliac bundles nearer the insertion, and the lowest again nearer the origin. The cremaster is supplied from the genito-femoral, that is from the second lumbar nerve.

The rectus receives its supply from the sixth or seventh to the twelfth thoracic nerves, and sometimes from the first lumbar nerve. The nerves are connected by loops, and the number of twigs which enter the muscle is much in excess of the number of spinal nerves distributed to the muscle. The supply to the sections of the muscle is not strictly segmental, owing to the junction of neighbouring nerves. The main supply to the upper division is from the seventh, to the second portion from the eighth, and to the third section from the ninth intercostal nerve. The post-umbilical part of the muscle is supplied from the tenth, eleventh, and twelfth intercostal nerves and sometimes from the first lumbar. The line of entrance is in the lateral part of the muscle, in the lower part of the muscle along the lateral border. The pyramidalis is supplied from the twelfth thoracic and first lumbar nerves, sometimes from the first and second lumbar nerves, or from the second lumbar only.

Actions of the Abdominal Muscles.—The abdominal muscles serve a variety of purposes. Their action in respiration has already been considered (p. 188), and the part they play in flexion of the vertebral column has also been described (p. 175). If the thorax be fixed by the extensors

¹ Lat., *Adminiculum*—a prop, support, or stay.

of the spine the abdominal muscles may act on the pelvis; thus in the act of climbing, the trunk and arms being elevated and fixed, the pelvis is drawn upwards, either directly or to one side, as a preparatory step to raising of the lower limbs. When both thorax and pelvis are fixed the muscles act in combination to constrict the abdominal cavity and compress the viscera, particularly if the diaphragm is also fixed by closure of the glottis, as occurs in vomiting and the expulsion of the foetus, the faeces, or the urine. The constricting force of the combined muscles is very considerable. The expulsive force has been calculated (General Myology, p. 8), and is stated to amount to as much as 32.9 lbs. on each square inch of the abdominal wall.

Latero-Dorsal Muscles in the Lumbar Region

This group of muscles is a small one. It consists only of the lateral inter-transverse muscles of the loins, which have, for convenience, been described in an earlier section, and the quadratus lumborum. It has been already explained that the lumbar myotomes, with the exception of the first, and to a small degree, perhaps, the second, do not take any share in the formation of the muscles of the abdominal wall, and that the ventro-lateral sheet is represented only by its dorsal portion from which these muscles are derived. The musculature has been pushed caudally and dorsally by the backward extension of the derivatives of the more cranial myotomes.

M. Quadratus Lumborum (fig. 76, p. 223).—This muscle is a strong quadrilateral sheet, rather broader below than above, which extends between the iliac crest and the last rib, close to the vertebral column. It consists of three systems of fasciculi, *ilio-costal*, *ilio-transverse*, and *transverso-costal*. The ilio-costal bundles form the lateral part of the muscle. They arise behind by fleshy, in front by tendinous fibres from the ilio-lumbar ligament and the iliac crest for about 4 or 5 cm. of its extent, and ascend nearly vertically to be inserted into the lower border and inner surface of the last rib along the medial half of its extent. The posterior bundles do not extend so far medianwards, either at the origin or the insertion, as the anterior fasciculi. Thus the anterior fibres arise from the ilio-lumbar ligament, and at their insertion generally extend on to the part of the body of the twelfth thoracic vertebræ adjoining the head of the rib and its transverse process, sometimes also to the intervertebral disc below and the body of the second lumbar vertebra. The ilio-transverse fasciculi are exposed on the posterior aspect of the muscle, and are more or less overlapped by the ilio-costal bundles. They arise from the iliac crest and form four fleshy bellies which are attached to the lower borders of the transverse processes of the upper four lumbar vertebræ, by tendinous slips placed, as a rule, behind the slips arising from these processes. The fleshy slips are closely related medially to the lateral intertransverse muscles. The transverso-costal fasciculi are seen on the anterior aspect of the medial part of the muscle. They arise by fleshy and tendinous slips from the tips and upper borders of the transverse processes of the lower three or four lumbar vertebræ, and ascending join the anterior vertical ilio-costal fibres to be inserted with them into the last rib.

Relations.—The quadratus lumborum is related behind to the transverse processes of the lumbar vertebræ and the so-called middle layer of the lumbar fascia. Its ventral surface is covered by a fascia which is connected laterally with the middle layer, and is commonly known as the anterior layer of the lumbar fascia. Its anterior surface is overlapped by the psoas muscle, and upon it rests the kidney, while the ascending (or descending) colon lies in front of its lateral border.

Varieties.—The muscle varies according to the degree of development of the vertebral slips, some of which may fail, or may be exposed by a reduction of the vertical fibres. The insertion of the muscle has been seen to extend to the eleventh rib.

Nerve Supply.—The quadratus is supplied by small branches from the twelfth thoracic and upper three lumbar nerves, which come off the ventral trunks near their origin.

Fasciæ of the Abdomen

The **superficial fascia of the abdomen** is usually described as consisting of two layers. Both layers are continuous with the superficial fascia on the other parts of the trunk, and they can be dissected as distinct layers only on the fore part of the abdomen, especially in the immediate neighbourhood of the groin, where subcutaneous vessels, such as the superficial epigastric and circumflex iliac, as well as lymphatic glands, lie between them. The *subcutaneous layer* corresponds in its general features with the areolar subcutaneous tissue of other parts of the body, and contains embedded in it a very variable and often large quantity of fat. The *deeper layer* is of a denser and more membranous structure, and contains a considerable amount of yellow elastic tissue. It is connected to the underlying aponeurosis of the external oblique by loose areolar tissue only, except at the umbilicus and along the linea alba, where the attachment is more intimate. From the lower part of the linea alba and the front of the symphysis pubis, a fibrous and elastic expansion of considerable strength, derived from this layer, passes to the dorsum of the penis, forming the *ligamentum fundiforme penis*, or *suspensory ligament* (fig. 69) of that organ. There is a certain amount of crossing of the fibres forming the ligament in the middle line. The superficial fibres end in the subcutaneous tissue of the penis, and also, at the sides, extend to the scrotum; the deeper and main mass of the ligament forms a sling round the base of the penis and is continued along the organ to end on the crura. The lower part of the deeper layer in the region of the groin is known as the *fascia of Scarpa*. It is continued freely downwards over the inguinal ligament, and becomes blended with the fascia lata immediately below the ligament. In the region of the superficial inguinal ring, however, it passes uninterruptedly down over the spermatic cord to the scrotum. On the scrotum the two layers are not separate and the fat disappears in the subcutaneous tissue, which here acquires a reddish-brown colour. This is due to the tissue becoming mingled largely with involuntary muscular fibres, constituting the *dartos tunic* of the scrotum. Some involuntary muscular fibres also exist in the altered superficial fascia which covers the penis. The dartos covering, on leaving the scrotum posteriorly, becomes continuous with the superficial fascia of the perineum.

The elastic lamella of the superficial fascia of the abdomen corresponds with the strong membrane composed almost entirely of yellow elastic tissue which in some lower mammals contributes to the support of the viscera. This *tunica abdominalis* is well seen in the horse or ox. The elastic tissue in these animals also provides an elastic covering and support for the inguinal mammae.

Underneath the superficial fascia the external oblique muscle has a fascial layer over its fleshy portion. Over the aponeurosis of the external oblique the fascial covering of the muscular sheet, becoming very thin, is fused with the tendinous sheet. On the surface of the aponeurosis above the inguinal ligament a system of fibres is seen coursing medianwards from the outer part of the inguinal ligament and the region of the anterior superior iliac spine (fig. 69). The highest of these sweep upwards and medianwards, the intermediate are transverse, the lowest extend over the region of the superficial inguinal ring, and connect its pillars together. These intercolumnar or incruval fibres have been variously interpreted, some holding that they represent fibres which course lateralwards from the aponeurosis of the opposite side, others that they are only constituent fibres of the fascia which covers and is blended with the aponeurosis. In any case, whether fascial or tendinous in origin, their presence is explained by the

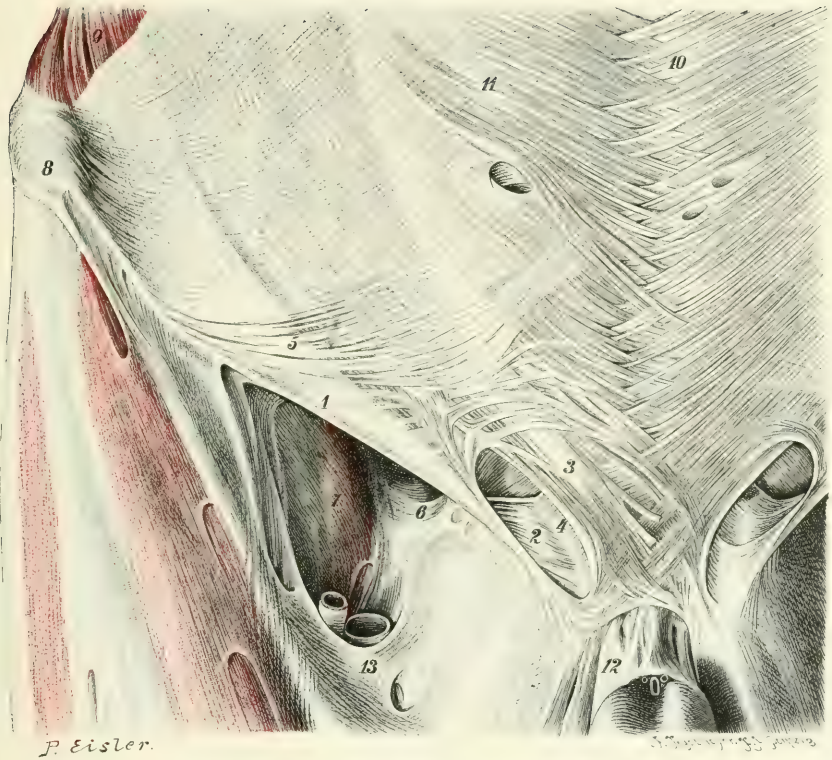


FIG. 69.—FASCIA OF INGUINAL REGION; SUPERFICIAL INGUINAL RING, ETC.

1, inguinal ligament; 2, Gimbernat's ligament; 3, medial pillar of superficial inguinal ring; 4, reflex inguinal ligament; 5, intercolumnar fibres; 6, processus falciformis lacunaris; 7, fascia iliaca in femoral canal; 8, ant. sup. iliac spine; 9, M. obliq. abdom. ext.; 10, linea alba; 11, sheath of rectus abdom.; 12, lig. suspensor. penis; 13, inferior horn falciform process of fascia lata. (Eisler.)

distending forces to which this relatively weak part of the abdominal wall is exposed.

The broad muscles of the wall of the abdomen are separated from one another by strata of loose connective tissue, in places condensed into fascial layers. On the deep or visceral surface of the transverse muscle there is a more definite fascia, which along with the fascia of the psoas and iliacus muscles, and the lamella on the surface of the quadratus lumborum, forms a general fascial lining to the muscular wall of the abdomen. In an account of the fasciæ which is systematic rather than topographical, it will be convenient to deal with the posterior layers in the first instance.

The **fascia of the quadratus lumborum**, or anterior layer of the lumbar fascia, has already been mentioned. It is attached, at the medial border of the muscle, to the front of the transverse processes of the lumbar vertebræ, while along the lateral border it becomes united with the middle layer of the fascia. Inferiorly it is attached to the iliac crest and the ilio-lumbar ligament; superiorly it is thickened to form the lateral arched ligament of the diaphragm already described.

The **fascia of the psoas muscle** commences above at the medial arched ligament of the diaphragm with which it is blended, and below it is directly continued into the iliac fascia of which, indeed, it is merely the upward extension. Laterally it joins the fascia of the quadratus lumborum along the border of the psoas, while medially it is attached to the intervertebral discs, the adjoining parts of the bodies of the lumbar vertebræ as well as the fibrous arches over the lumbar vessels, and lower down to the ala of the sacrum.

The **iliac fascia** (fig. 70) is a denser layer which stretches transversely from the iliac crest, over the iliacus and psoas, to the brim of the pelvis. It is continued downwards under the inguinal ligament covering the conjoined muscle as it lies in the groove between the anterior inferior iliac spine and the ilio-pectineal eminence, and follows it into the thigh. As it passes under the inguinal ligament, it is firmly attached to it, and to the transversalis fascia for a certain distance; but where the external iliac artery and vein pass over the brim of the pelvis into the thigh, it is separated from the inguinal ligament and the transversalis fascia by the vessels, and is prolonged into the thigh behind them. Below the outer part of the inguinal ligament it merges with the fascia lata, forming the upper part of the sheath of the sartorius muscle. Behind the vessels it becomes continuous with the fascia of the pectineus (pubic portion of fascia lata). From the inguinal ligament downwards it thus forms the postero-lateral boundary of the grooved recess in which the femoral vessels lie. It forms the lateral wall, and, in association with the fascia of the pectineus, the posterior wall of the femoral sheath. From the line of union of the iliac with the pectineal fasciæ a short but strong intermuscular septum is sent backwards between the psoas and pectineus muscles to be attached to the ilio-pectineal eminence and the capsule of the hip-joint.

In cases where a psoas parvus is present the iliac fascia is thickened above the ilio-pectineal eminence by the incorporation of the tendon of the muscle as it expands at its insertion.

The **fascia transversalis** is strongest at the lower part of the abdomen where the muscular and tendinous support is somewhat weaker. Over the rest of the abdominal wall it is a thin layer which is in places fused with the fibrous layer of the parietal peritoneum. Followed upwards from above the groin it becomes gradually slighter, and at the margin of the ribs it is continued into a thin areolar layer on the under aspect of the diaphragm. Traced towards the middle line it is seen to extend as a fine fascial layer on the aponeurosis of the transverse muscle

and the posterior wall of the sheath of the rectus to the linea alba in which its fibres are incorporated. Below the level of the semilunar fold of Douglas it becomes very thin and lax, and alone forms the wall of the sheath of the rectus. It is, however, strengthened by various strands of fibres running in different directions, which are provided by the transverse aponeurosis of the same or the opposite side. It often happens that the semilunar fold is indistinct, or apparently double. This is due to the presence of fibres from the transverse aponeurosis which continue to pass behind the rectus, and are blended with the fascia. On the posterior wall of the abdomen the fascia merges in that of the quadratus lumborum, but below, along the margin of the iliac crest it is attached to the periosteum between the attachments of the transverse and iliac muscles, or it may be implanted directly on the iliac fascia. For about two inches medial to the anterior superior iliac spine it is connected with the back of the inguinal ligament and the iliac fascia. About the middle of the ligament the transversalis and iliac fasciæ, which are directly united up to this point, separate from one another, and between the two layers the external iliac artery and vein intervene. It is continued downwards on the vessels to form the antero-medial wall of the funnel-shaped femoral sheath. Along the lateral aspect of the vessels the fascia transversalis and fascia iliaca continue to be united with one another and so complete the sheath on its outer side. On the medial side the relations are rather more complicated. As the prolongation of the fascia passes under the inguinal ligament, it is strengthened by a dense band of fibres constituting the *deep crural arch*, or *ilio-pubic tract* (fig. 70). This band is narrow in the middle, but spreads out laterally and medially; it extends in a transverse direction and is only loosely attached to the inguinal ligament. It reaches from the region of the anterior superior iliac spine to the upper border of the pubic bone and the ilio-pectineal line behind the rectus tendon and the conjoined tendon of the internal oblique and transverse muscles. It curves over the vessels, and includes beneath it, medial to the vessels, a space between Gimbernat's ligament and the vein, sufficiently large to admit the point of the little finger. This is known as the *femoral ring*, and is the space through which a femoral hernia descends. The fascial expansion which is continued downwards from this deep crural arch to form the anterior wall of the femoral sheath, is connected with Gimbernat's ligament, and extends backwards to blend with the fascia of the pectineus. In this way it forms the medial boundary of the femoral ring and the medial wall of the femoral sheath down to the saphenous opening (*fossa ovalis*) where it merges with the cribriform fascia.

At a point a little to the medial side of the middle of the inguinal ligament, and 10 to 15 mm. above it, the spermatic cord in the male, or the round ligament in the female, enters the gap in the abdominal wall known as the inguinal canal. These structures carry with them a funnel-shaped prolongation of the transversalis fascia (*infundibuliform fascia*) into the canal. The abdominal opening of this funnel is named the deep inguinal ring. The fascia on the upper and lateral side of the ring is thin, but below, and to the inner side, it is thickened by fibres of the ilio-pubic tract radiating into it, and longitudinal fibres descending from above. The opening is thus bounded below by a distinct crescentic edge, over which the spermatic cord or round ligament passes (fig. 70). An oblique inguinal hernia descends through the ring and canal, and the infundibuliform fascia forms one of its coverings.

Between the deep inguinal ring and the rectus muscle, the posterior wall of the inguinal canal is formed by the fascia transversalis, and as a general rule it is further strengthened by a falciform tendinous sheet named the *conjoined tendon* or *falx aponeurotica inguinalis* (fig. 70); sometimes also by fibres from the trans-



FIG. 70.—ANTERIOR ABDOMINAL WALL FROM BEHIND, THE BLADDER AND PERITONEUM BEING REMOVED TO DEMONSTRATE THE FASCIAL LAYERS. The cross indicates the position of the anterior superior iliac spine.

1, the ilio-pubic tract; 1', its semilunar edge bounding the deep inguinal ring; 2, fascia on lacunar ligament; 3, falx (aponeurotica) inguinalis (conjoined tendon); 4, spermatic cord; 5, muscular fibres in the interfoveolar fold; 6, cremaster muscle; 7, M. transversus abdom.; 8, adminiculum; 9, M. rectus abdom.; 10, girdle-like thickening of fascia transversalis; 11, linea semilunaris (Douglasi); 12, ext. iliac vessels; 13, fascia iliaca; 14, M. ilio-psoas; 15, symphysis pubis; 16, prostate; 17, ligg. pubo-prostatica; 18, fascia obturatoria; 19, obturator vessels. (Eisler.)

verse aponeurosis which occupy the projecting fold between the medial and lateral inguinal pouches of peritoneum, and hence named the *ligamentum interfoveolare*.

The name conjoined tendon is retained here to represent one form of *falx aponeurotica* which is definitely derived from the separate pubic attachment of the conjoined aponeuroses of the transverse and internal oblique muscles. The degree to which the internal oblique contributes tendinous fibres to the structure varies, and some refer the whole falciform expansion to the transversus. The degree to which it is developed varies greatly, and in many bodies it is absent altogether. In some cases the rectus tendon itself extends lateralwards on the ilio-pectineal line, or is prolonged along the line by a union with its lateral border of tendinous fibres derived from the transverse aponeurosis. Another variation is sometimes observed when fibres of the transverse aponeurosis placed at a higher level descend vertically along the lateral border of the rectus to be attached to the pubic bone (Kenneth Douglas). This may co-exist with a conjoined tendon. Lastly a falciform expansion, consisting of fibres connected with the border of the rectus tendon, and the sheath in front of it, may occupy the angle between rectus and pubic bone. It may be stronger than the real falx or conjoined tendon (Spalteholz).

MUSCLES AND FASCIÆ OF THE PELVIS

The muscles to be described in this section are the levator ani, the coccygeus, and two vestigial muscles occasionally present, the anterior and posterior sacro-coccygeus. The last named, which is a derivative of the dorsal musculature, represents the extensor muscles of the caudal vertebræ of the lower animals. The other muscles are derived from the ventral sheet and represent the flexors and abductors of the tail of lower forms. The anterior sacro-coccygeus is a variable and rudimentary slip of no functional importance in the human subject. The coccygeus and levator ani represent certain caudal muscles which in man have assumed a new rôle. With the reduction and fusion of the caudal vertebræ they have lost their primary function, and now form a muscular diaphragm to the pelvic outlet. The levator ani plays the chief part in contributing to this diaphragm, and to the support of the viscera, especially of the rectum, necessitated by the assumption of the erect attitude, and the widening of the pelvic basin.

M. Levator Ani (figs. 71, 72).—The levator ani muscle is a broad and thin fleshy sheet which arises from the back of the pubic bone and the side wall of the pelvis, and is inserted into the coccyx and the ano-coccygeal raphe, while a certain number of fibres pass to the perineal body, in front of the anus. The medial edges of the two muscles separate from one another to permit of the passage of the anal canal, on the walls of which some of the muscular bundles descend to blend with those of the sphincter muscles. The levator ani of descriptive anatomy generally shows a partial cleft beginning just below the obturator canal, and this cleavage corresponds to a morphological separation of the sheet into two parts distinct in lower mammals, named the *pubo-coccygeus* and the *ilio-coccygeus* muscles. The former only has a direct connexion with the rectum.

M. Pubo-coccygeus.—This division of the levator ani sheet arises by tendinous and fleshy fibres from the back of the pubic bone along an oblique line which extends from the lower part of the symphysis upwards and lateralwards to the anterior margin of the obturator canal, where it meets, or is sometimes overlapped by, the ilio-coccygeus muscle. From this origin the fibres pass downwards and backwards and are distributed as follows (fig. 71): (1) The most anterior fibres, closely surrounding the prostate gland in the male, or the vagina in the female, pass into the perineal body in front of the anus. There they decussate with the fibres of the opposite muscle, and certain of them, descending on the anal canal, terminate in the external sphincter ani and skin of the anus. (2) The

greater number of fibres sweep nearly horizontally backwards on the side of the anal canal to unite, behind the passage, with those of the muscle of the other side. This system of fibres may be grouped, following the description given by Thompson, in two sets: (a) A set of antero-posterior fibres which, uniting with those of the other side behind the rectum, form a thick fibro-muscular band. This band lies upon, and is more or less incorporated with, the raphe formed by the ilio-coccygei muscles, and reaches the coccyx to the point of which it is attached by

two slips (*anterior sacro-coccygeal ligaments*). (b) A deeper set of fibres which arise from the pubic bone and pubic arch under cover of the others, and sweeping round the anal canal join the fibres of the opposite side to form a strong loop which slings the rectum up to the symphysis pubis (*M. pubo-rectalis*).

As the muscles sweep round the anal canal a few fibres are said to descend upon it between the external and internal sphincter muscles, but this has been denied by some authorities (Holl, Thompson).

M. Ilio-coccygeus.—

This division of the muscle does not arise directly from the bony wall of the pelvis except at the ischial spine, but by a fascial sheet which covers the upper part of the obturator internus, and has generally been known as the parietal layer of the pelvic fascia, or the pelvic part of the obturator fascia.

This fascial sheet stretches from the obturator canal to the great sciatic

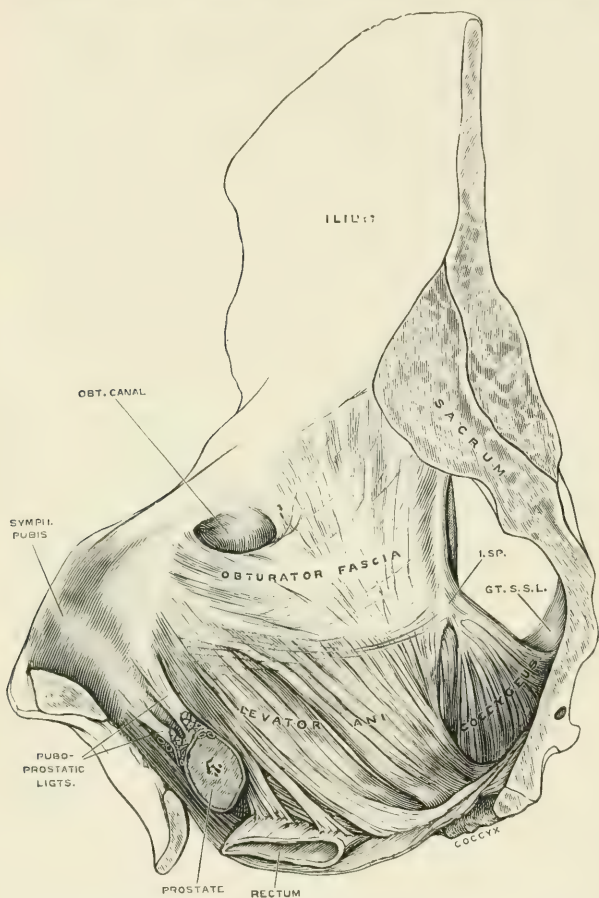


FIG. 71.—LEVATOR ANI AND COCCYGEUS MUSCLES OF THE RIGHT SIDE, FROM WITHIN. (Drawn by T. W. P. Lawrence.) $\frac{1}{2}$

I.S.P., ischial spine; GT.S.S.L., great sacro-sciatic ligament.

notch. Anteriorly it is attached to the upper margin of the obturator membrane where this bounds the obturator canal, and it forms an arch over the vessels and nerve issuing through that canal. Behind the canal it merges with the periosteum along a line which follows the border of the obturator internus. This falls below the ilio-pectineal line in front, but rises to the level of the line near the sacro-iliac joint. From this point the membrane fuses with the periosteum downwards along the margin of the sciatic notch to the ischial spine. Here some of the muscular fibres of the ilio-coccygeus find a direct bony attachment. In front of the obturator canal the fascial sheet is replaced by the epimysial lamella on the

pubo-coccygeus, but in a dissection it is generally to be made out that while this lamella is adherent to the muscle, the hinder part of the fascial sheet is easily separable from the obturator internus, over which it lies. The muscle fibres of the pubo-coccygeus sometimes fall short of the obturator canal, and in this case the fascial sheet (the so-called obturator fascia) will extend in front of the canal and find attachment to the ascending ramus of the pubic bone.

The lower arched border of the fascial membrane thus defined, along the line where it is continuous with the sheet of fleshy fibres generally shows a thickening known as the *arcus tendineus musculi levatoris ani* (fig. 71). The *arcus tendineus* is always attached behind to the ischial spine, but its anterior extremity varies in position.

To understand the significance of these details it is necessary to study the varieties of the muscle, and its comparative anatomy. The muscle in lower mammals to which the ilio-coccygeus corresponds arises from the pelvic brim. In rare cases the muscle fibres are found, even in the human subject, arising from the pelvic brim along the line to which the fascial sheet just described is fixed. In this event an epimysial lamella alone covers the muscle, continuous of course with the similar layer on the pubo-coccygeus. Now, ordinarily the attachment of the ilio-coccygeus slips down on the pelvic wall, but not always to the same extent, and we may meet with one or other of several different arrangements: (1) The upper part of the fleshy sheet becomes replaced below the pelvic brim by a thin aponeurosis¹ on which scattered muscle fibres ascend. (2) This aponeurosis becomes reduced to a fascial membrane, but along the line where the fleshy fibres spring from it is thickened, and this thicker margin forms a tendinous arch (*arcus tendineus m. levatoris ani*). This arch is attached behind to the ischial spine, but terminates in front at a variable level either behind, or just in front of, the obturator canal. (3) The membranous aponeurosis may be absent altogether. In this case the obturator internus is exposed, covered by a thin fascial layer, the true obturator fascia, and an *arcus tendineus* stretches across the surface of the muscle, and may even be separated from it by a pocket. In this latter case the *arcus* is found to extend forwards over the face of the pubo-coccygeus, but without being fixed to it, to be attached to the lower border of the back of the body of the pubic bone. Such a tendinous arch is equally, according to Derry, a thickening of the aponeurosis of the ilio-coccygeus. It is generally present in the normal condition of parts where the fascial membrane exists, and it is quite common for this lower *arcus tendineus* to co-exist with a second higher up on the pelvic wall in cases where scattered muscle bundles rise above its level, and the aponeurosis to which they are attached ends in a free edge. This lower *arcus* is the so-called "white line" or *arcus tendineus fasciæ pelvis* (*B.N.A.*), as distinguished from the *arcus tendineus m. levatoris ani*, and so named on the assumption that it is a fascial thickening.²

From a consideration of these variable conditions and a study of the comparative anatomy of the ilio-coccygeus, we must look upon this fascial sheet as representing more than the sheath of the obturator internus. It represents the aponeurosis of the ilio-coccygeus, conjoined with its muscle sheath. This is continuous with the epimysium of the muscular sheet below, but as in all other cases where an aponeurosis exists, the epimysial fascia becomes reduced and adherent and cannot be raised as a continuous layer over the aponeurosis. The membrane will vary in density according to the number of the tendinous bundles persisting in it.

From their origin along the side wall of the pelvis, in this fashion, the fibres of the ilio-coccygeus are directed downwards, backwards, and medially to be inserted into the lateral margin of the last two pieces of the coccyx, and into a median raphe which extends from the tip of the coccyx to the anus.

At their insertion the muscle bundles, according to Thompson, are arranged in layers superimposed upon each other. The upper layer consists of the posterior fibres going to the coccyx ;

¹ This term is used here in the sense defined on p. 16.

² Cf. Delbet and Rieffel in Poirier and Charpy, "Traité d'Anatomie Humaine."

the middle layer is composed of fibres which decussate in the middle line without forming a fibrous raphe; whilst the lowest layer forms the fibrous raphe into which most of the muscle is inserted.

Occasionally a band of muscle is met with placed on the ventral aspect of the coccygeus muscle. It arises from the side wall of the pelvis below the ilio-pectineal line, and is inserted into the lateral border of the sacrum. It is known as the *ilio-sacralis* and represents the dorsal part of the more extensive ilio-coccygeus of some lower mammals.

M. Coccygeus (figs. 71, 72).—This muscle is a thin flat triangular sheet, composed of fleshy and tendinous fibres which arise from the spine of the ischial bone, from the obturator fascia above the spine, from the margin of the great sacro-sciatic foramen, and from the sacro-spinous ligament. It is inserted by its base into the lateral margin of the lower two sacral and upper two coccygeal vertebræ.

The coccygeus represents in vestigial form the abductor caudæ of lower animals. It is subject to considerable variation. It is sometimes strong and fleshy but is generally replaced to a large extent, or even completely, by fibrous tissue.

M. Sacro-coccygeus Anterior.—This name is given to some muscular bundles and tendinous slips which pass from the front of the lower sacral vertebræ to the coccyx. It represents in vestigial form the depressor caudæ muscle, or muscles, of lower animals. It is frequently but not invariably present.

M. Sacro-coccygeus Posterior consists of some delicate muscular slips which arise from the dorsal aspect of the sacrum or posterior inferior iliac spine, and extend to the back of the coccyx. It is the caudal continuation of the dorso-lateral musculature, and is represented in long-tailed mammals by a medial and lateral extensor and a dorsal abductor of the tail (Lartschneider).

Musculus Recto-coccygeus.—This is a slip of non-striped muscular fibres which arises on each side of the middle sacral artery from the last sacral and first coccygeal vertebræ, unites with its fellow in the middle line, and passes on to the back of the rectum. Some authorities state that it is constant but variable, others regard it as a mere variety.

Innervation.—The *levator ani* is supplied partly by twigs from the third and fourth sacral nerve which enter its pelvic surface and partly also by branches from the internal pudendal (pudic) nerve which pierce its outer aspect (Thompson). The *coccygeus* gets its supply from the third and fourth sacral nerves, sometimes also from the fifth, and in rare instances from the second and third (Eisler). The twigs enter the cranial border and pelvic surface of the muscle.

Action of the Pelvic Muscles.—The vestigial flexor and extensor muscles of the coccyx have no functional importance in the human subject.

The levator ani and coccygeus act principally in supporting and to a certain extent raising the floor of the pelvis. They thus come into play with the muscles of the abdominal wall in forcible expiratory and other expulsive efforts. This is the sole function of the coccygeus and the ilio-coccygeal portion of the levator ani. The pubo-coccygeus, forming as it does a muscular sling attached to the pubic bone in front and coccyx behind, affords more powerful support to the superimposed parts, and raises the pelvic floor after it has been depressed during defæcation, parturition, etc. It acts with its fellow, however, also on the rectum, constricting the canal which it thus helps to empty, and at the same time, in virtue of the post-rectal loop, carrying the anus upwards and forwards towards the pubic symphysis.

MUSCLES OF THE PERINÆUM

This group of muscles, closely bound up as they are with the foregoing muscles, belong to an entirely different category. They are derived in development from a subcutaneous sphincter muscle surrounding the cloacal depression, and represent, taken together, the common and undivided cloacal sphincter of the lower forms in which there is a single cloacal chamber.

In an embryo of the second month the cloacal sphincter is still present. With the division of the internal cloaca and the establishment of separate openings for the rectal and urogenital divisions of the chamber, the single ring-like muscle becomes resolved into two portions, an anal and a urogenital. The anal division becomes the external sphincter ani in both sexes. The urogenital sphincter,

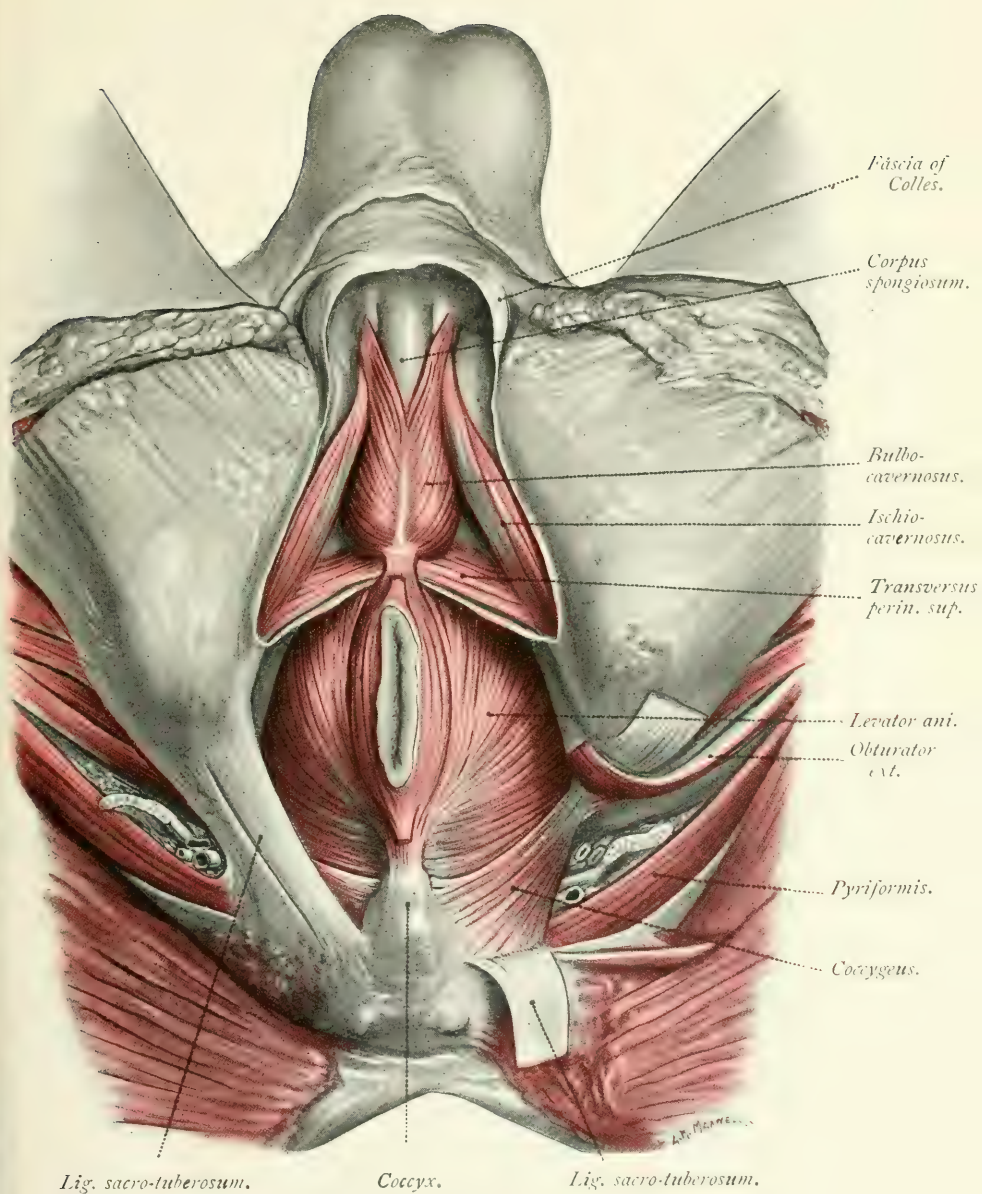


FIG. 72.—DISSECTION OF THE MUSCLES OF THE PERINEUM.

becoming connected with the pubic arch, gives origin to the ischio-cavernosus, the bulbo-cavernosus, the superficial and deep transverse perineal muscles, and the sphincter of the urethra. In the female subject the primitive arrangement is more nearly adhered to as the bulbo-cavernosi remain apart and surround the vaginal orifice. The common sphincter is innervated by the internal pudendal nerve. With the division of the sphincter the nerve likewise divides into two main divisions, hæmorrhoidal and perineal, from which twigs are given off to the several muscles.

A. Anal Muscles

Sphincter ani Externus (fig. 72).—The *external sphincter* is to be distinguished from the *internal sphincter* which is a thick ring of unstriated muscle continuous with the circular fibres of the rectum, and is generally described with the anatomy of that organ. The external sphincter is placed, on the other hand, immediately below the skin. It forms a band of fibres nearly an inch in depth on each side and surrounds the margin of the anus. It is elliptical in form, and is attached posteriorly by a small tendon to the tip of the coccyx, usually receiving also some fibres from the overlying integument. Passing forwards it divides into two parts to enclose the anus, uniting again anteriorly. Here the superficial fibres end in the skin, some of the innermost decussating across the middle line, but the larger part, becoming blended with those of the transverse and bulbo-cavernosus muscles, are attached in the median plane to the fibrous matrix of the perineal body. In the female subject the arrangement of fibres is essentially the same.

Closer analysis shows that the muscle may be resolved into layers. The most superficial fibres lie immediately below the skin, surround the anal aperture, and decussate in front of and behind the opening, but do not reach the coccyx. The deeper fibres surrounding the lower part of the anal canal generally show a distinction into two lamellæ. The more superficial fibres are attached to the coccyx behind, and it may be to the ano-coccygeal raphe. In front they become tendinous in the perineal body, some ending in the skin, while many are continuous with the bulbo-cavernosus. The fibres of the deep stratum are intimately connected with the puo-rectal fibres of the levator ani, and surround the rectum behind without being attached to the coccyx. In front of the anus, according to Thompson's account, some of the fibres cross to the opposite side and reach the ischial bone, forming the transversus perinæi superficialis.

Transversus Perinæi Superficialis (fig. 72).—This is a very variable slip of muscle fibres disposed transversely and extending from the inner aspect of the ischial tuberosity above and below the level of the attachment of the ischio-cavernosus, and it may be from the border of the triangular ligament, to the middle line. Here the fibres end in the perineal body and are continuous with those of the external sphincter, the bulbo-cavernosus, as well as those of the opposite muscle. In the female subject the bony attachment is generally more extensive so that the muscle tends to be triangular in form.

The muscle is frequently absent. Sometimes it consists of several separate fasciculi and it may be inserted wholly or in great part into the bulbo-cavernosus or external sphincter. According to Thompson the fibres of the chief part of the last-named muscle cross the middle line and run to the ischial ramus in the transverse muscle. He regarded the muscle as representing a bony attachment for the sphincter, affording it support, and helping in retraction of the anus. A muscular slip is occasionally found springing from the fascia at the lower border of the glutæus maximus, and running into the transversus perinæi, or being inserted into the triangular ligament.

B. Genito-Urinary Muscles

(1) *Superficial Muscles*

M. Bulbo-cavernosus (fig. 72).—In the male, the bulbo-cavernosus muscle is united with its fellow of the opposite side in a median raphe continued forward from the central point of the perineal body. The two muscles cover the bulb and the adjacent part of the corpus spongiosum. The fleshy fibres arise from the perineal body, where they are connected with those of the transverse muscle and the sphincter ani, and from the tendinous raphe. They are disposed in layers overlapping one another, and are directed outwards and forwards over the corpus spongiosum and root of the penis. The fibres from the perineal body and posterior part of the raphe invest the bulb, and winding round it, ascend between the corpus spongiosum and corpus cavernosum to end by joining the fibres of the opposite side in a fibrous aponeurosis which covers the dorsal aspect of the corpus spongiosum, and is placed between it and the conjoined corpora cavernosa. Some of the posterior fibres end on the triangular ligament. The fibres from the anterior part of the raphe encircle partially or wholly the root of the penis, forming when well developed a narrow band which is attached to the corpus cavernosum in front of the ischio-cavernosus. This band may end in a fibrous expansion on the dorsal aspect of the penis covering the dorsal vessels and nerve, or may even be continued by fibres into the tissue in front of the body of the pubic bone.

The muscle may be resolved (Thompson) into four parts. The first, *ischio-bulbosus*, is an inconstant slip arising from the tuberosity of the ischium and extending over the bulb. The second, *compressor bulbi proprius*, includes the greater number of the fibres described above. The third, *constrictor radialis penis*, is represented by the anterior fibres of the foregoing description. The fourth portion, *compressor hemisphaerium bulbi*, described first by Kobelt (1848), forms the deepest layer of the muscle. It invests the free rounded end of the bulb. Its fibres converge on a flat, narrow median tendon continuous with the opposite muscle and placed on the dorsal aspect of the bulb just in front of the point where the membranous urethra enters it.

In the female the two bulbo-cavernosi muscles surround the orifice of the vagina by which they are separated from one another. The two muscles together form what is generally called the sphincter vaginae. The fibres arise from the perineal body and receive fibres both from the superficial sphincter ani and the transverse perineal muscles. From this point they extend forwards and outwards on each side, encircling the vaginal orifice, and covering the vaginal bulbs and the glands of Bartholin. Anteriorly the outermost fibres on each side are attached to the pubic arch, blending with the triangular ligament and the corpus cavernosum clitoris; the middle fibres cross the crus of the clitoris and end in the region of the suspensory ligament of that organ, some fibres reaching the mons veneris; the innermost fibres pass into the prepuce of the clitoris, the anterior vaginal wall, and the tissue between it and the urethra. All these fibres are placed lateral to the bulb of the vagina, but another system of fibres placed on the medial side of the bulb and glands of Bartholin is described. These surround the vulvar orifice at the level of the hymen and are intimately connected behind with the sphincter ani; they end in front in the vaginal wall and the tissue which connects this with the urethra, and in the prepuce of the clitoris.

The name *sphincter vaginae* should strictly be reserved for those deeper fibres surrounding the vagina. There is nothing to correspond with them in the male. The remainder of the fibres on each side are arranged like those of the bulbo-cavernosus of the male, and can be analysed like it into *ischio-bulbosus*, not regularly present, *compressor bulbi proprius*, and *constrictor radialis clitoridis*. The *compressor hemisphaerium* is not represented.

M. Ischio-cavernosus (fig. 72).—This muscle embraces the crus penis and extends forwards from the ischial tuberosity along the pubic arch. It arises from the inner aspect of the ischial tuberosity and frequently also from the sacrotuberous ligament. Along the ischial and pubic rami it is attached on each side of the crus. It is chiefly muscular behind but in front is markedly tendinous. It ends on the side of the penis in a tendinous expansion which is attached to the under and outer aspect of the crus at its forward part.

The fibres may be resolved into three sets: (1) Medial and posterior fibres which, arising from the ischial tuberosity, end in front on the under side of the penis at the angle between the corpora cavernosa. The tendinous fibres may reach the middle line and joining with those of the opposite side form an intercruial ligament. (2) Intermediate fibres which surround the crus and spring from the tuberosity and ramus of the ischial bone. They end as tendinous bundles on the fibrous sheath of the crus on its lateral aspect. (3) Lateral fibres which arise from the conjoined ischial and pubic rami and end like the last on the crus but further forwards. In a small number of cases another system of fibres springs from the pubic bone and extends over the dorsum of the penis. It may represent, as Thompson suggested, the most anterior fibres of the primitive sphincter, and probably corresponds to a similar detached bundle of the muscle in lower mammals. It has also been named the *compressor venæ dorsalis penis*. This muscle occurs in well-marked form in carnivores, but the slip referred to is not, according to Thompson, homologous with it. He regarded as its true homologue a small vestigial muscle named *ischio-pubicus*. This arises from the ischio-pubic ramus ventral to the constrictor urethræ, and ends in a tendon which, joining with its fellow, crosses the pubic arch below the dorsal vein.

In the *female* the ischio-cavernosus is almost the exact counterpart of the muscle in the male. It is, in keeping with the smaller size of the crus clitoridis as compared with the crus penis, of more slender proportions, and according to Thompson's account it is more tendinous. The forward part of the crus is covered by a flat tendon which receives all the muscular fibres.

(2) Deep Muscles

M. Sphincter, or Constrictor Urethræ.—Round the membranous urethra is placed a composite mass of muscular fibres. Some of these extend transversely or obliquely across the pubic arch, while others surround the urethra in a circular manner. These last form, in the strict sense of the term, the constrictor or sphincter of the membranous urethra. The muscle fibres are striated, and are to be distinguished from the proper plain muscle fibres of the wall of the urethra. They extend from the prostate to the bulb. The transverse fibres are arranged as follows: Anteriorly one set springs from the transverse pelvic ligament, the fascial layers between which they lie, and according to some authors also from the pubic ramus. They meet with the fibres of the other side in a median raphe, a few passing in front of the urethra, but the greater number behind it.

In certain lower mammals each gland of Cowper receives a separate muscular investment (*compressor glandulæ Cowperi*) from this system of fibres. In man a detached slip or layer of fibres related to the gland corresponds to this muscle.

In almost direct continuity with the transverse fibres of the sphincter urethræ, but on a slightly different plane, is another group of transverse bundles arising from the pubic arch where ischial and pubic rami join. They extend to the median plane, join in a median raphe with those of the opposite side, and extend back as far as the central point of the perineal body. They constitute what is known as the **M. transversus perinæi profundus**, described by many authors as a separate muscle, but by others considered as part of the sphincter urethræ.

In the *female* the sphincter urethræ is more difficult to demonstrate than in the male. It is more interpenetrated by smooth muscle fibres. The circular system of fibres arises from the connective tissue surrounding the urethra between the symphysis and the neck of the bladder and the walls of the veins of the venous plexus, which lies on the anterior wall of the vagina and urethra, and ends in the dense tissue between the urethra and vagina. The arrangement of the transverse fibres is generally the same as in the male, but is modified by the presence of the vagina. The anterior or upper fibres pass partly in front of the urethra to join those of the opposite side, partly behind the urethra in the tissue between it and the anterior vaginal wall. The hinder fibres are directed medianwards and downwards and blend with the vaginal wall. The *transversus profundus* arises as in the male, but here it ends in the anterior vaginal wall posterior to the urethra, and behind this again in the central point of the perineal body. In both sexes this mass of transverse muscle fibres stretches across and closes the gap between the pubo-coccygei muscles, and thus completes the pelvic floor in front. With its associated fascial lamellæ it is known as the *urogenital diaphragm*.

Nerves of the Perineal Muscles.—The sphincter ani externus is supplied by the inferior hæmorrhoidal branch of the internal pudendal nerve, and by a branch from the fourth sacral. All the rest of the muscles receive their supply by twigs from the perineal division of the internal pudendal nerve.

Actions of the Muscles.—The *external sphincter* muscle occludes the anal orifice. Closure is maintained by the tonic contraction of the muscle, but can be rendered firmer by an act of the will. The action of the internal sphincter is wholly involuntary. The external sphincter also assists the *transverse perineal muscles* in fixing the perineal body when the genito-urinary muscles come into action.

The *ischio-cavernosus* muscles in contracting serve to compress the roots of the corpora cavernosa, so increasing the tension in the erectile tissue of the penis or clitoris.

The *bulbo-cavernosus* muscles in the male serve the same purpose by compressing the bulb and adjoining part of the corpus spongiosum. By the pressure exerted on the spongy part of the urethra they also help to empty the urethra. They come into action at the end of the process of micturition when their contraction is mainly a voluntary one, and in the emission of semen when it is involuntary. In the female the bulbo-cavernosus muscles, by compressing the bulbs of the vagina, increase and maintain the blood tension in the erectile tissue of the clitoris. They also act as a sphincter apparatus for the vulvar orifice.

The *transversus profundus* supports the raphe and perineal body, and in the male also provides a muscular basis of support for the prostate and seminal vesicles.

The *constrictor urethræ* diminishes the calibre of the membranous urethra and comes into action at the close of micturition to empty the urethra, and in emission as an accessory ejaculator. In the female it acts as a sphincter of the urethra.

PELVIC AND PERINEAL FASCIÆ

Fascia on the Upper Aspect of the Pelvic Floor.—In the description given on p. 205 *seq.* of the levator ani it was shown that the two muscles form an almost complete lining to the cavity of the pelvis from brim to outlet. Only the sacrum, sacro-iliac foramina, and the back of the pubic bones are left uncovered. The two levator muscles meet in the median plane in the rectal part of the pelvic outlet to form the rectal diaphragm which is complete, save where it is perforated by the anal canal. Posteriorly on each side of the coccyx the pelvic floor is completed by the coccygei muscles, while the lateral parts of the sacrum are covered, and the sacro-iliac foramina occupied, by the pyriformis muscles. In front, behind the pubic symphysis, the two muscles stand apart, and through the gap between them passes the urethra in the male, the urethra and the vagina in the female. A mass of muscular tissue and certain fascial lamellæ associated with

the urogenital passages close this gap, fill the angle of the pubic arch, and complete the floor of the pelvic cavity in this region.

When the peritoneum is stripped off the upper aspect of the pelvic floor a thick substratum of connective tissue is exposed, covering the side walls and floor of the pelvic basin. Derived from the continuous and undifferentiated mesenchyme of the embryo, this tissue by local condensations provides connective tissue coats for the viscera, sheaths for the ducts, vessels, and nerves which traverse it, and epimysial lamellæ on the pelvic face of the muscles. A complete account of the coats of the viscera and of the vascular sheaths, derived from the *subperitoneal tissue* in the restricted sense, belongs rather to a descriptive account of the

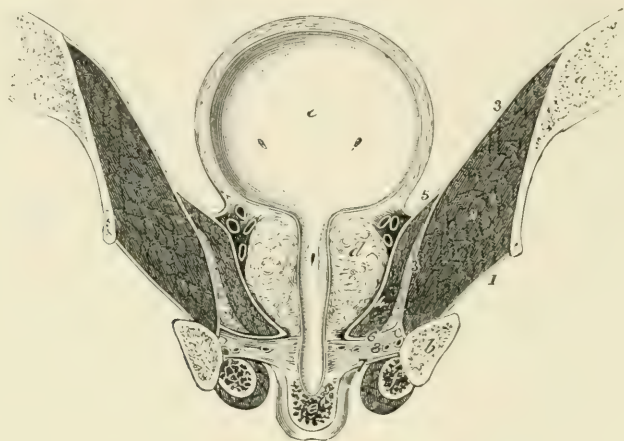


FIG. 73.—CORONAL SECTION OF THE PELVIS IN THE SITUATION INDICATED BY THE LINE A, A', IN FIG. 74, SHOWING THE DISPOSITION OF THE PELVIC FASCIA AND TRIANGULAR LIGAMENT OF THE URETHRA (SEMIDIAGRAMMATIC). (G. D. T.)

a, section of the hip-bone passing through the centre of the acetabulum; *b*, section of the ramus of the ischium; *c*, bladder, from which the urethra is continued downwards; *d*, prostate gland; *e*, corpus spongiosum urethræ, covered by the bulbo-cavernosi muscles; *f*, crus penis, covered by the ischio-cavernosus muscle; 1, obturator membrane; 2, obturator internus muscle; 3, 3, obturator fascia; 4, levator ani muscle; 5, recto-vesical fascia, dividing into an ascending layer attached to the bladder, and a descending layer forming the sheath of the prostate: between the fascia and the prostate are the veins of the prostatic plexus; 6, superior, and 7, inferior layer of the urogenital diaphragm; 8, constrictor urethræ muscle, embedded in which, close to the ischium, are the pudendal vessels and the dorsal nerve of the penis.

In order to show more clearly the relations of the parts, the urethra is represented as being laid open through the whole of the prostatic and membranous and the commencement of the spongy portions; whereas the lower half of the prostatic portion is naturally a little behind the plane of the section.

viscera of the pelvis. Here attention will be directed mainly to the sheaths of the muscles and their connexions.

When the looser connective tissue is dissected away a fascial lamella of considerable density comes into view on the side wall of the pelvis. It is specially strong in the interval between the obturator canal and the sacro-iliac foramen. Here it covers the pelvic surface of the obturator internus muscle, but as already explained (p. 207) it is not to be looked upon as the ordinary fascia of the muscle. We have, on theoretical grounds, shown reason for regarding it as representing the aponeurosis of the ilio-coccygeus muscle reduced to a fascial layer. On its parietal surface it is applied to the true fascia of the obturator muscle, while on the pelvic surface it is covered, in the undisturbed condition of parts, by a thick layer of subperitoneal tissue in which the obturator vessels are embedded as they pass to the obturator canal. Posteriorly, the aponeurosis ceases at the sacro-iliac foramen, to the anterior border of which it is attached; the subperitoneal tissue is continued over the foramen where, greatly increased in amount, it surrounds the issuing vessels

and nerves, and gives a fascial sheath to the pyriformis muscle. Anteriorly the fascial lamella arches round the vessels issuing through the obturator canal, and is attached to the free upper border of the obturator membrane where it bounds the opening. Medial to the obturator canal the membrane is continuous along an arched line (*arcus tendineus m. levatoris ani*) with the fascia which covers the upper part of the pubo-coccygeus. But this is a true epimysial layer and of course corresponds only with the epimysial constituent of the fascial lamella (see p. 207). It merges with the periosteum along the line of attachment of the muscle to the back of the pubic bone. When a distinct *arcus tendineus fasciæ pelvis* is present, attached to the lower part of the body of the

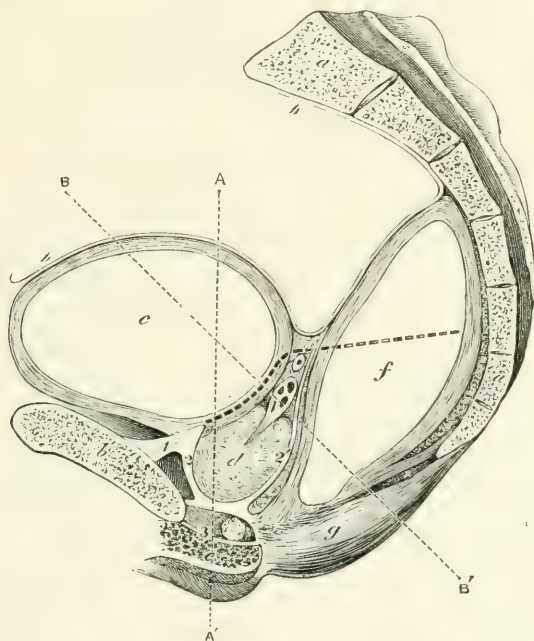


FIG. 74.—DIAGRAM OF A SAGITTAL SECTION OF THE PELVIS, A LITTLE TO THE LEFT OF THE MEDIAN PLANE, TO SHOW THE ARRANGEMENT OF THE PELVIC FASCIA, ETC. (G. D. T.) $\frac{1}{2}$

a, a, section of sacrum and coccyx; *b*, section of pubis; *c*, bladder; *d*, prostate gland, above which are the vesicula seminalis and ductus deferens cut obliquely; *e*, corpus spongiosum urethræ, covered by the bulbo-cavernosus muscle; *f*, rectum; *g*, external sphincter; *x*, levator ani; *1*, anterior true ligament of bladder; *2, 2'*, sheath of prostate, continuous below with the upper layer of the urogenital diaphragm; the hinder part of the sheath is continued upwards between the vesiculæ seminales and the rectum; *3*, inferior layer of the urogenital diaphragm, between which and the superior layer are seen in section the constrictor urethræ muscle and Cowper's gland; *4, 4*, peritoneum.

The thick dotted line indicates the level at which, to the left of the section, the ascending layer of the recto-vesical fascia is attached to the bladder and rectum. The thinner dotted lines *A, A'* and *B, B'* represent the situation of the sections shown in figs. 73 and 75.

pubic bone, we find that the sheath of the pubo-coccygeus, exposed on the wall of the pelvis above the level of the arch, is fairly dense and membranous, whereas below the arch it is looser and less membranous in texture. The fascial layer on the pelvic surface of the pubo-coccygeus is of course separated from the obturator internus muscle by the attachment of the muscle to the pubic ramus. The lower, or outer surface, of the pubo-coccygeus is for a certain distance bound to the obturator muscle by a stratum of fascia which represents the merged sheaths of the two muscles.

Returning to the ilio-coccygeal part of the levator ani we find that an epimysial lamella is developed over the fleshy part of the muscle. This is continued backwards as a delicate layer over the coccygeus muscle and is attached to the side of the coccyx, while between this and the anus it merges in the ano-coccygeal raphe.

In the region of the sacro-iliac foramen the subperitoneal connective tissue gives a dense

sheath to the vessels and nerves. It is attached to the margins of the foramen and is continued as a fascial layer on the pelvic surface of the pyriformis to the sacrum, where it merges with the periosteum to the medial side of the sacral foramina. The nerves issuing from these foramina are invested by this fascia. They lie with the vessels on the face of the pyriformis muscle, and both sets of structures may be said to be embedded in its sheath.

It may be noted in passing that the dense connective tissue surrounding and supporting the vessels in the region of the sacro-iliac foramen is prolonged round the vessels proceeding to the viscera over the pelvic floor. There are thus formed bands and accumulations of connective tissue of importance, theoretical and practical, in connexion with the support of the viscera, but which do not fall to be described in detail here.

In the region of the rectum the epimysial layers on the pelvic surfaces of the levator ani muscles necessarily become continuous with the connective tissue coat of the gut, where it passes between the two muscles, and are continued with it on the wall of the rectum to the anus (rectal layer). These arrangements are practically identical in both sexes, but the distribution of the fascia in the fore part of the pelvic cavity is necessarily different in the male and female. In the male the neck of the bladder and the prostate, as they occupy the interval between the two pubo-coccygeus muscles, are surrounded by an accumulation of subperitoneal connective tissue in which there runs a plexus of large veins. Round the prostate this tissue is condensed to form the matrix supporting the venous plexus and a connective tissue investment to the gland. On the lateral aspect of the prostate this is merged with the fascia covering the adjacent pelvic surface of the pubo-coccygeus. At the base of the gland the venous plexus and its investing tissue, still continuous with the sheath of the pubo-coccygeus, pass on to the bladder. The sheath of the pubo-coccygeus is here supported and strengthened by the arcus tendineus fasciæ pelvis sweeping round the neck of bladder and prostate to the back of the pubic bone. There is thus formed the structure known as the *lateral true ligament* of the bladder by which that viscus and with it the prostate are firmly fixed to the pelvic floor. Above the prostate the subperitoneal tissue is also condensed on each side to form two strands passing from the back of the pubic bone to the front of the neck of the bladder, the so-called pubo-prostatic ligaments. These contain some unstriated muscle bundles continued from the bladder, and are therefore sometimes named the pubo-prostatic muscles. Between the two ligaments the front of the sheath of the prostate is formed by a thin lamella which bounds the pubo-prostatic space. Below, this sweeps upon the urethra to be continuous with the transverse ligament of the pelvis (see p. 218). This is the only part of the sheath of the prostate directly adherent to the substance of the gland. Between the rectum and the prostate there intervenes a dense lamella of connective tissue which is continuous above with the investment of the seminal vesicles and merges towards the perinæum in the perineal body. This *recto-vesical septum* is continuous laterally with the matrix in which the prostatic venous plexus is embedded, and so indirectly with the fascia on the pelvic face of the levator ani.

This lamella, known as the prostato-peritoneal fascia of Denonvilliers, was described by Cuneo and Veau as arising, not from a simple accumulation of subperitoneal connective tissue but from the fusion of the opposing peritoneal surfaces of the recto-vesical pouch. In the foetus the pouch extends to the lower edge of the prostate, but is obliterated during foetal life in its distal part by the fusion of the serous layers and merging of the subserous lamellæ of connective tissue.

In the female the distribution of the fascial lamellæ is much the same as in the male, but in place of the sheath of the prostate it is the connective tissue covering the vaginal wall that is merged with the fascial sheath of the pubo-coccygeus. The connective tissue which lies between rectal and vaginal walls below the level of Douglas' pouch corresponds with the prostato-peritoneal fascia in the male.

Fasciæ on the Perineal Aspect of the Pelvic Floor

Superficial Fascia.—In the posterior half of the perinæum the subcutaneous fat is continued deeply into the ischio-rectal fossa, the pyramidal space intervening between the pelvic wall and the levator ani muscle. In the anterior half of the perinæum, beneath the subcutaneous fat, is placed a special layer of fascia, continuous with the dartos, the proper *superficial perineal fascia*, sometimes called *fascia of Colles*. It covers the superficial muscles of the urethral triangle of the perinæum, and the fact that these are derived from the primitive sphincter cloacæ explains the relations and connexions of the fascia. It is bound down on each side to the margin of the rami of the pubis and ischium as far back as the ischial tuberosity; posteriorly, along a line from the ischial tuberosity to the central point

of the perinæum, it turns round the hinder margin of the transversus perinei muscle to join the deep perineal fascia, to be presently described. From its deep surface, likewise, an incomplete median septum passes upwards towards the urethra and is continued forwards into the scrotum. In front the fascia is continuous with that of the penis, with the fascia of the spermatic cord, and with the fascia of Scarpa on the abdominal wall. It thus happens that air blown in beneath the proper perineal fascia on one side passes forwards and distends the scrotum to a certain extent on that side; it may then penetrate to the other side also, and if injected with sufficient force may reach the front of the abdomen, and travel upwards beneath the superficial fascia; but it neither passes backwards to the posterior half of the perinæum nor downwards upon the thighs. The same course is followed by urine extravasated beneath the proper perineal fascia.

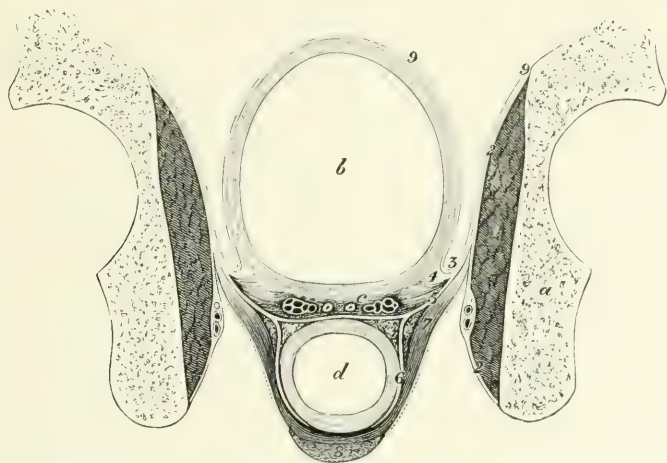


FIG. 75.—DIAGRAM OF AN OBLIQUE SECTION OF THE PELVIS IN THE SITUATION INDICATED BY THE LINE B, B' IN FIG. 74. (G. D. T.) $\frac{1}{2}$

a, section of hip-bone, passing behind the centre of the acetabulum; *b*, bladder; *c*, vesicula seminalis and ductus deferens of the right side; *d*, rectum; 1, obturator internus muscle; 2, 2, obturator fascia, in the lower part of which the pudendal vessels and nerves are contained in a sheath; 3, recto-vesical fascia; 4, its upper layer attached to the bladder; 5, its lower layer passing across in front of the rectum, and continuous with 6, the lateral part of the investment of the rectum; 7, levator ani, the dotted line on its surface indicates the position of the anal fascia; 8, external sphincter; 9, 9, peritoneum.

Deep Fascia.—The levator ani muscle as it descends to the pelvic outlet is at first closely applied to the obturator internus muscle. In the region of the obturator membrane and pubic bone the pubo-coccygeus and the obturator muscle are united by a layer of fascia, which represents the merged fascial sheaths of the two muscles. Behind this the ilio-coccygeus and obturator muscles are also connected by a fascial layer, but as the levator draws away from the pelvic wall this becomes resolved into an epimysial lamella on the obturator internus (*obturator fascia*), a corresponding but much more delicate layer on the levator ani (*anal fascia*), and an intervening stratum of areolar tissue. As the gap widens between the levator and the pelvic wall the areolar tissue is, by the deposit of fat, converted into the adipose tissue which occupies the so-called ischio-rectal fossa.

The *anal fascia*, so called, is continued on the levator ani to the anus. It covers the whole of the perineal face of the levator ani which is free, and therefore extends from a line drawn from behind the pubic bone, where it covers the pubo-coccygeus, to the ischial spine, downwards to the anus. The *obturator fascia* is a denser membrane, and is attached to the inner margin of the ischial tuberosity and falciform process of the sacro-tuberous ligament. Here it is merged with the sheath of the internal pudendal vessels, forming Alcock's canal, but the sheath continues to surround the vessels as they pass forward, and following the border of the pubic

arch along its whole length, it ultimately blends with the matrix of the prostatic plexus of veins behind the transverse ligament of the pelvis.

It has already been stated in general terms that the name urogenital diaphragm is given to a mass of tissue, with muscular and connective tissue constituents, which closes the gap between the medial edges of the pubo-coccygeus muscles, fills the angle of the pubic arch, and completes the floor of the pelvic cavity in front. We must now consider the parts more in detail.

The name *perineal body* is given to a mass of connective tissue which occupies the angular space between the anal canal and urinogenital passages. The subcutaneous perineal muscles, as we have seen, are attached to, or decussate in, this mass of tissue which has also received the name *central point of the perineum*. On a deeper plane the anterior fibres of the pubo-coccygei muscles invade the body, and intercross with one another in the median plane. In the female the perineal body merges about 4 cm. from the surface in the tissue between the rectal and vaginal walls. In the male the connective tissue of the perineal body, where rectal ampulla and membranous urethra come into more or less close apposition, forms a recto-urethral septum. Here non-striped muscle fibres enter into its composition, and they stretch across between the medial borders of the pubo-coccygei muscles. In front of this mass of tissue the membranous urethra descends from prostate to bulb for a distance of about 1.4 cm. It is surrounded by the circular fibres of its sphincter, and is bound to the pubic arch on each side by a sheet of transverse fibres (*transversus perinaei profundus*). This lamella of fleshy fibres is necessarily covered by an epimysial sheath on both faces, and these constitute what are known as the *superior and inferior fasciae of the urogenital diaphragm*.

The *superior lamella* lies entirely behind the urethra. It is a fairly distinct membrane, but it represents more than the epimysial layer of the deep transverse muscle. It consists of this merged (1) with the tissue of the perineal body where it intervenes between the medial edges of the pubo-coccygei muscles, and (2) with the fascia on the *perineal* surfaces of these muscles lateral to their medial margins, that is, with the anal fascia on each side at the extreme upper and anterior part of its extent.

The *inferior lamella* is better defined and is developed into a fairly resistant membrane for a specific purpose. Apparently a simple triangular lamella pierced by the urethra, it really consists of two parts or overlapping planes. The *posterior part* is trapezoidal in form. It is attached on each side to the ischial and pubic rami above the corpus cavernosum penis and is here merged with the sheath of the internal pudendal vessels. The adventitious sheath of the urethral bulb is continuous with it—or put otherwise, the fascia splits to enclose the bulb, between two lamellæ, of which the upper (or posterior) is the stronger. It serves, therefore, not only as an epimysial layer but as a support or suspensory apparatus for the bulb, and may legitimately be called the *triangular ligament of the bulb*.¹ It merges with the perineal body posteriorly, and of course with the superior fascial lamella at the level of the hinder border of the deep transverse muscle. Anteriorly it follows the posterior wall of the urethra into the angle between it and the bulb. Between the triangular ligament and the superior fascia of the urogenital diaphragm as defined above are included the constrictor urethræ, deep transverse perineal muscles, and the bulbo-urethral glands of Cowper. The internal pudendal vessels are not strictly included between these lamellæ. They lie on each side in a sheath merged with the attachment of the triangular ligament to the pubic arch.

The *anterior portion* of the membranous lamella has the form of a well-marked band of fibrous tissue which is attached, on each side, to the pubic ramus, and crosses the subpubic angle above the urethra. It is known as the *ligamentum transversum pelvis*. It is separated from the symphysis pubis and subpubic ligament by a gap through which the dorsal vein of the penis enters the pelvis. It is intimately bound up at its pubic attachments with the sheaths of the internal pudendal veins which drain the prostatic venous plexus. It is connected with two fascial lamellæ which may be described as anterior and posterior extensions of the transverse band. The anterior extension follows the upper (anterior) wall of the urethra and upper aspect of the corpus spongiosum. It extends between this and the crura of the corpora cavernosa penis, which it binds together just before their union with one another. The posterior extension has already been mentioned in connexion with the prostatic sheath. It sweeps along the upper aspect of the urethra to that gland, and then covers its anterior surface.

In the female the arrangement of the fascial layers is much the same, only complications are introduced by the presence of the vagina. Both superior and inferior lamellæ merge with the adventitious sheath of the vagina. The triangular ligament in the restricted sense is weaker than in the male, but has the same relations to the vestibular bulbs. These and the vagina are as it were enclosed between two lamellæ just as is the urethral bulb in the male.

¹ A better title would be *ligamentum trapezoideum bulbi*, but it seems better to preserve the old name, triangular ligament, for this part of the so-called fascia trigoni urogenitalis inferior.

THE MUSCLES AND FASCIÆ OF THE LOWER LIMB

In the case of the upper limb it was seen that a number of large and important muscles extended to the pectoral girdle and humerus from the trunk. The general arrangement and detailed features of these muscles have been determined by the mechanism of the movable pectoral girdle, and the very free and extensive movements of the arm. Apart from the trapezius this series of muscles includes some which take origin developmentally within the limb bud and thence spread over the trunk, and others which are derived directly from the ventro-lateral sheet of muscles and find attachment to the pectoral girdle. They take an essential part in effecting the various displacements of the girdle which so much extend the scope of the movements of the arm. The pelvic girdle is, on the other hand, immovably fixed to the vertebral column and all this girdle musculature is absent. The muscles derived from the ventro-lateral extensions of the myotomic sheets become attached, as we have seen, to the pelvic girdle and form the muscular wall of the abdomen. We have thus in the lower limb nothing comparable to the extensive limb muscles which spread over the trunk in the case of the upper extremity. Certain muscles do spread from their seat of origin to the skeleton of the trunk, but they are few, and only in the instance of the psoas muscle is the spread extensive. The pyriformis muscle extends its attachments to the ventral aspect of the sacrum, and the glutæus maximus becomes fixed to the dorsal aspect of both sacrum and coccyx. All the other limb muscles have their origin confined to the girdle itself. In lower mammals, however, a number of muscles extend their attachments to the caudal part of the vertebral column; thus the hamstring muscles have a vertebral origin, and in some forms there is a separate caudo-femoral muscle.

Another reason for the more limited extension of the limb muscles attached to the trunk is the greater extent of surface for muscular attachment provided by the pelvic girdle.

THE FASCIÆ OF THE HIP AND THIGH

The **superficial fascia** of the lower limb is similar to and continuous with that of other parts of the body. Over the gluteal region it is very thick and assists in forming the prominence of the buttock. On the front of the thigh it covers the lymphatic glands and the superficial vessels and nerves; it passes freely over the inguinal ligament, becoming continuous with the subcutaneous layer of the abdominal fascia, and medially it passes into the dartos tunic of the scrotum and into the superficial fascia of the perinæum. In the neighbourhood of the groin a thin layer of condensed areolar tissue, placed beneath the glands and superficial vessels, can be raised from the surface of the fascia lata, and is sometimes described as a deep layer of the superficial fascia. The structure is continued across the saphenous opening of the fascia lata, to the margins of which it is closely attached, and being here perforated by numerous small foramina for the passage of blood vessels and lymphatics it receives the name of *cribriform fascia*. As in the arm the fascia includes between its lamellæ the superficial veins and the superficial nerves.

Fascia Lata.—The term fascia lata is used here to designate the deep fascia of the thigh. It is a strong membrane consisting of white shining fibrous tissue, and in parts is tendinous in character. While of unequal thickness at different parts it forms a continuous infundibuliform sheath round the limb. Posteriorly this sheath-like investment ceases at the gluteal fold where the fascia is markedly

thickened. Above this point the surface of the glutæus maximus is covered by a fascia of a different character from elsewhere, and this is again continued between the proximal border of the muscle, the iliac crest, and the tensor fasciæ latæ, by a dense tendinous sheet covering the glutæus medius. On the lateral aspect of the thigh in a vertical line from the iliac crest, in the region of the tubercle, to the lateral condyle of the tibia, a definite band of dense glistening parallel fibres, which it is possible to isolate from the transverse or fascial fibres proper, constitutes the insertion of the tensor fasciæ femoris and of part of the glutæus maximus. This is known as the *ilio-tibial band* (fig. 79, p. 237), or in the B.N.A., *tractus ilio-tibialis*, a name adopted from Welcher and used to signify that the fibres of which the band is composed are not fascial so much as tendinous, or in other words pass through rather than form part of the fascia proper. Speaking generally the fascia is attached round the base of the limb to the back of the sacrum and coccyx, the iliac crest, the inguinal ligament, the body of the pubic bone and its ramus, the ischial ramus, the ischial tuberosity, and the lower margin of the sacro-tuberous ligament. In the gluteal region the thick tendinous lamellæ over the glutæus medius descending from the iliac crest to the upper border of the glutæus maximus divides into two layers, one on the superficial and one on the deep aspect of the muscle. The superficial layer is thin, but remarkable for the strong septa which pass into the muscle between its muscular fasciculi; it consists of fibres running parallel to the fasciculi. The two layers after encasing the muscle unite at its distal and lateral borders. Near the great trochanter where the layers unite externally and where they merge in the ilio-tibial band, the greater number of the fibres of the muscle are inserted between the layers. The dense fascia over the glutæus medius is intimately connected in front with the longitudinal tendinous fibres which descend over the trochanter from the tubercle of the iliac crest, and which form the trochanteric part of the ilio-tibial band. Over the great trochanter the band receives a large accession of tendinous bundles from the glutæus maximus, and lower down at the junction of the upper and middle thirds of the thigh also from the tensor fasciæ latæ. If the band thus formed by the longitudinal tendinous fibres be traced downwards it will be found that the larger number pass vertically to be attached to the outer condyle of the tibia, some sweep forward to the lateral border of the patella as the *lateral patellar ligament*, while others incline backwards to find insertion into the lateral lip of the linea aspera in the lateral intermuscular septum. These longitudinal fibres merged or interwoven with the fascia lata must be regarded strictly as the tendinous insertion of the glutæus maximus and tensor fasciæ latæ muscles, while the dense fascia over the glutæus medius represents a muscular sheet which once joined these two muscles into a single mass.

At the upper end of the ilio-tibial band, where the tensor fasciæ latæ joins it, a deep process passes upwards on the medial face of the muscle, to be attached to the iliac bone above the origin of the reflected head of the rectus femoris with which it is closely connected. Over the rest of the thigh the fascia varies in thickness. It is thinnest in the proximal and medial part of the leg, where it covers the adductor muscles. At the knee it is considerably strengthened on each side of the patella by tendinous expansions given off from the lower parts of the vasti muscles and assists in forming the capsule of the joint. This part of the fascia is firmly attached to the head of the tibia and to the margins of the patella, but a layer is given off which extends over the front of the latter bone, a synovial bursa of considerable size being interposed. A second smaller bursa is placed immediately under the skin covering the knee-cap, and the cavities of the two are

sometimes in communication through an aperture in the fascia. Other small bursæ are not infrequently present over the patella or its ligament, or over the tuberosity of the tibia. Posteriorly the fascia is continued uninterruptedly over the hamstring muscles and popliteal space into the fascia of the leg.

On the front of the thigh the fascia, descending from its attachment to the inguinal ligament between the anterior superior iliac spine and the pubic spine, covers the triangle of Scarpa. Here at a point below and a little external to the inner end of the inguinal ligament there is placed the *saphenous opening*, an aperture in the membrane through which the saphenous vein passes to join the femoral vein, and receives special attention from its being the place of exit of femoral hernia. The outer part of this opening lies in front of the femoral artery, and is bounded laterally by a crescentic margin, the falciform border, which crosses the surface of the infundibuliform sheath of the femoral vessels. The margin in the middle of its extent is continued into looser tissue, the above-mentioned cribriform fascia, but superiorly and inferiorly it ends in more distinct incurved extremities, the so-called superior and inferior cornua. The latter, the most completely defined portion of the margin, lies in the angle between the great saphenous and femoral veins below their junction; while the superior cornu forming a larger curve sweeps medialwards to the inner side of the femoral sheath to be attached to the front of Gimbernat's (lacunar) ligament. It is customary to call the parts of the fascia lata on the outer and inner sides of the saphenous opening the iliac and pubic portions. The *iliac portion* is intimately connected above with the inguinal ligament as well as with the deep layer of the superficial fascia of the abdomen (fascia of Scarpa), and medially forms the falciform margin of the saphenous opening. The *pubic portion* or *pectineal fascia* is attached superiorly to the ilio-pectineal line and passes over the surface of the pectineus in a lateral direction behind the sheath of the vessels, with which it is connected, to be continued into the iliac fascia as has already been described (p. 202).

The fascia lata is perforated in many places by foramina which allow of the passage of the numerous nerves and blood vessels.

From the deep surface of the membrane deep processes pass among the muscles. One of these already mentioned passes between the tensor fasciæ latæ and the vastus lateralis. Two others, named the *medial and lateral inter-muscular septa*, bind the fascia to the femur in the lower part of the thigh. The lateral septum, the stronger and better marked of the two, is situated between the vastus lateralis and crureus muscles in front and the short head of the biceps behind, and is inserted into the linea aspera from the tendon of the glutæus maximus to the lateral condyle of the bone. It is constituted by longitudinal fibres, and above the condyle forms a distinct band to be felt through the skin. The medial septum is much thinner and less distinct and is inserted into the femur between the adductor magnus and vastus medialis with the tendinous origins of which it is intimately blended.

Sheath of the Femoral Vessels.—The femoral vessels are surrounded by an investment of fascia which in its upper part is particularly distinct and receives the name of the *femoral sheath*. The constitution of this has been dealt with on p. 202. It is divided into three compartments separated by thin septa, the outer containing the artery and the middle the vein, while the innermost forms a space bounded above by the femoral ring and containing a lymphatic gland and some fat. Through this passage a femoral hernia descends, and on this account it has been named the *femoral canal*.

THE MUSCLES OF THE HIP

The muscles included in this group are the ilio-psoas anteriorly and the three glutæi and tensor fasciæ latæ covering the pelvis and hip-joint externally and posteriorly, and beneath the glutæus maximus the group of lateral rotators, viz. the pyriformis, the obturator internus with the gemelli, the obturator externus, and the quadratus femoris.

M. Ilio-psoas (fig. 76).—This is the great flexor muscle of the hip-joint. It is divisible into two parts, a broad lateral part, the iliacus, and an elongated medial part, the psoas magnus, which are sometimes described separately as two muscles. The greater part of the muscle is situated on the posterior wall of the abdomen, only the conjoined distal part appearing below the inguinal ligament over the front of the hip-joint. Although it rises high up on the lumbar part of the vertebral column, the ilio-psoas appears to be purely a limb muscle. It takes origin in the embryo in the base of the limb bud and migrates during development to its definitive position (Lewis).

The *iliacus* (fig. 76) arises from the upper half of the iliac fossa of the hip-bone, reaching down anteriorly to the inferior spine; it receives posteriorly a few fibres also from the ala of the sacrum and ligament connecting the two bones. The fasciculi converge as they pass downwards and inwards and are inserted for the most part into the lateral border of the tendon of the psoas. The outermost fibres, however, pass beyond that tendon and are attached directly to a special triangular surface on the proximal part of the femur, in front of and below the small trochanter.

The *psoas magnus* (fig. 76) arises by five fleshy slips from the anterior surfaces and lower margins of the transverse processes of the lumbar vertebræ; also from the bodies of the vertebræ by a series of thick processes, each of which takes origin from an intervertebral disc and from the contiguous margins of two bodies. The highest of these is attached to the last thoracic and first lumbar vertebræ, and the lowest to the fourth and fifth lumbar vertebræ and intervertebral disc between them. Further, thin tendinous arches extend over the vertebræ between these attachments, covering the lumbar vessels and communicating branches of the sympathetic; they also give origin to muscle fibres. The various bundles of fibres speedily unite to form a thick elongated muscle which runs along the brim of the pelvis and emerges from the abdomen beneath the inguinal ligament. The tendon is developed high up in the substance of the muscle, but lower down it appears as a large flat band along its lateral border. It receives the fibres of the psoas and also those of the iliacus which converge upon it in pennate fashion, and it is inserted into the lesser trochanter of the femur.

Relations.—Both iliacus and psoas are covered in the abdomen by the iliac fascia, which is also prolonged downwards over the conjoined muscles into the upper part of the thigh, where it becomes continuous with the pubic portion of the fascia lata. Superficial to the fascia are the subperitoneal fat and peritoneum, with the termination of the ileum, the cæcum, and the beginning of the ascending colon on the right side, and the lower part of the descending colon on the left side. The psoas at its upper extremity is placed behind the diaphragm, being crossed by the medial arched ligament: and below this the kidney with the ureter and renal vessels lie on the muscle, as well as the spermatic vessels and the genito-femoral nerve. The external iliac artery rests against its inner border along the brim of the pelvis, but lies over the muscle as it enters the thigh. The lumbar plexus of nerves is embedded deeply in the substance of the psoas, and its branches issue from the muscle at various points. The anterior femoral nerve passes into the thigh lying in the groove between the psoas and iliacus, and the ilio-inguinal and lateral cutaneous nerves cross the surface of the iliacus. The iliacus lies over the iliac bone, the anterior head of the rectus femoris, and the hip-joint, to the capsule of which a few of its fibres are sometimes attached. The psoas rests against the vertebræ, the quadratus lumborum, and the brim of the pelvis, over-

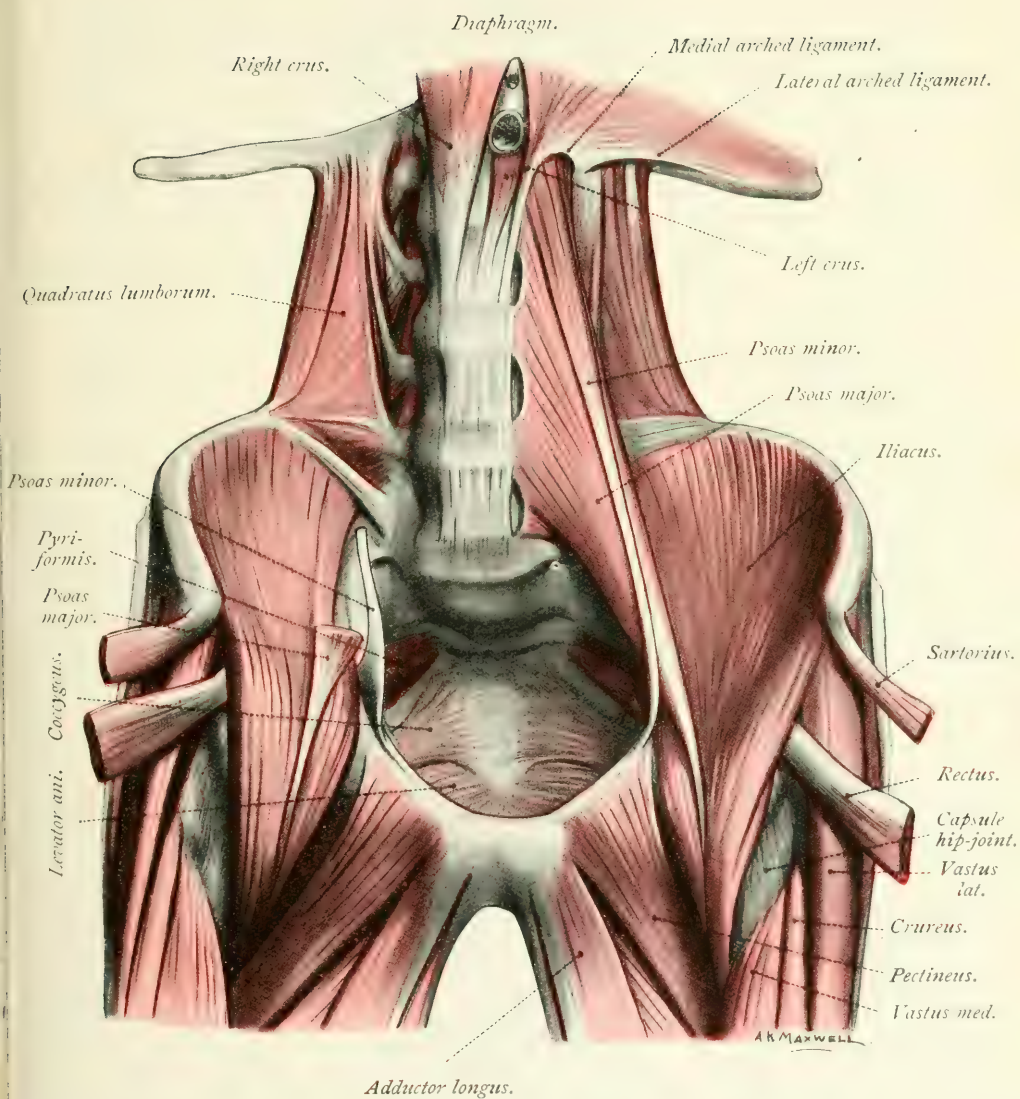


FIG. 76.—DISSECTION TO SHOW QUADRATUS LUMBORUM, PSOAS, AND ILIACUS MUSCLES, ETC. The psoas major and minor have been reflected on the right side to expose the ventral surface of the quadratus.

lapping also the inner border of the iliacus. The common tendon passes downwards in a deep groove between the anterior inferior spine and the ilio-pectineal eminence, and lower down, between the tendon and the capsule of the hip, is a large synovial bursa which sometimes communicates with the cavity of the joint.

Varieties. The psoas and iliacus are occasionally independent muscles as in the case of certain lower animals. The psoas may be divided longitudinally into fascicles. An accessory slip has been described lateral to the muscle and separated from it by the femoral nerve. The *iliacus minor* or *ilio-capsularis* is a small detached portion of the iliacus which is frequently present. It arises from the anterior inferior spine of the iliac bone and is inserted into the lower part of the intertrochanteric line of the femur, or into the ilio-femoral ligament.

M. Psoas Parvus (fig. 76).—This small muscle is placed on the surface of the psoas magnus. It consists of a short muscular belly arising from the bodies of the last thoracic and first lumbar vertebræ and from the disc between them, and a long flat tendon which passes along the front and inner margin of the psoas magnus, being incorporated with the iliac fascia and is inserted into the ilio-pectineal line.

This muscle, although well developed and constant in most lower animals, sometimes exceeding the psoas magnus in size, is not constant in man. Statistics from various sources show that it is present in 56 per cent. of bodies. When present it is liable to many changes in the place of origin. It may be connected only with the first lumbar vertebra, or with the second and the intervertebral disc above it; it has been observed to arise by two parts, or heads separated by an interval, or to be divided throughout. At its insertion it may end on the fascia iliaca, on the inguinal ligament, on the neck of the femur, or on the lesser trochanter with the psoas magnus. In the lower mammals when well developed it constitutes a flexor of the pelvis upon the vertebral column or *vice versa*.

Nerve Supply.—The ilio-psoas is supplied from the lumbar plexus. Twigs for the psoas magnus arise from the second, third, and fourth lumbar nerves as they lie in the substance of the muscle, and for the iliacus from the third and fourth nerves generally through the trunk of the femoral nerve. The psoas parvus is supplied by fine twigs from the loops between the second, third, and fourth lumbar nerves.

M. Glutæus Maximus (fig. 77).—This very large and coarsely fasciculated muscle is the chief extensor of the hip-joint.

Its great size and the consequent prominence of the buttock is a characteristic of man as compared with those animals which most nearly approach him in general structure. This great development of the muscle is clearly related to the assumption of the erect posture by man. The muscle is not itself actively concerned in maintaining the extended position of the hip, this being effected without muscular effort, but it plays an important part in supporting the knee in the standing posture. It then acts over two joints, as will be explained fully below, and the fact must be borne in mind in studying the muscle.

The muscle is nearly quadrilateral in shape. It arises from the posterior fourth of the iliac crest, and from the rough surface of the bone between this and the posterior gluteal line, from the back of the last two pieces of the sacrum and first three pieces of the coccyx, from the sacro-tuberous ligament, and from the aponeurosis of the erector spinæ muscle between the sacrum and the iliac bone. Some fibres also arise from the fascia over the glutæus medius. The fasciculi descend parallel to one another in a downward and outward direction, and are inserted as follows: the whole of the upper part of the muscle and the superficial fibres of the lower part end on tendinous fibres which sweep into, and form a large part of, the longitudinal fibrous bundles of the ilio-tibial band; the deeper and larger portion of the lower half of the muscle is attached by a flattened tendon to the gluteal ridge on the proximal third of the shaft of the femur.

Relations.—The glutæus maximus is superficial throughout. Its medial and distal part is rendered specially prominent by the subjacent ischial tuberosity, and thus forms, with a consider-

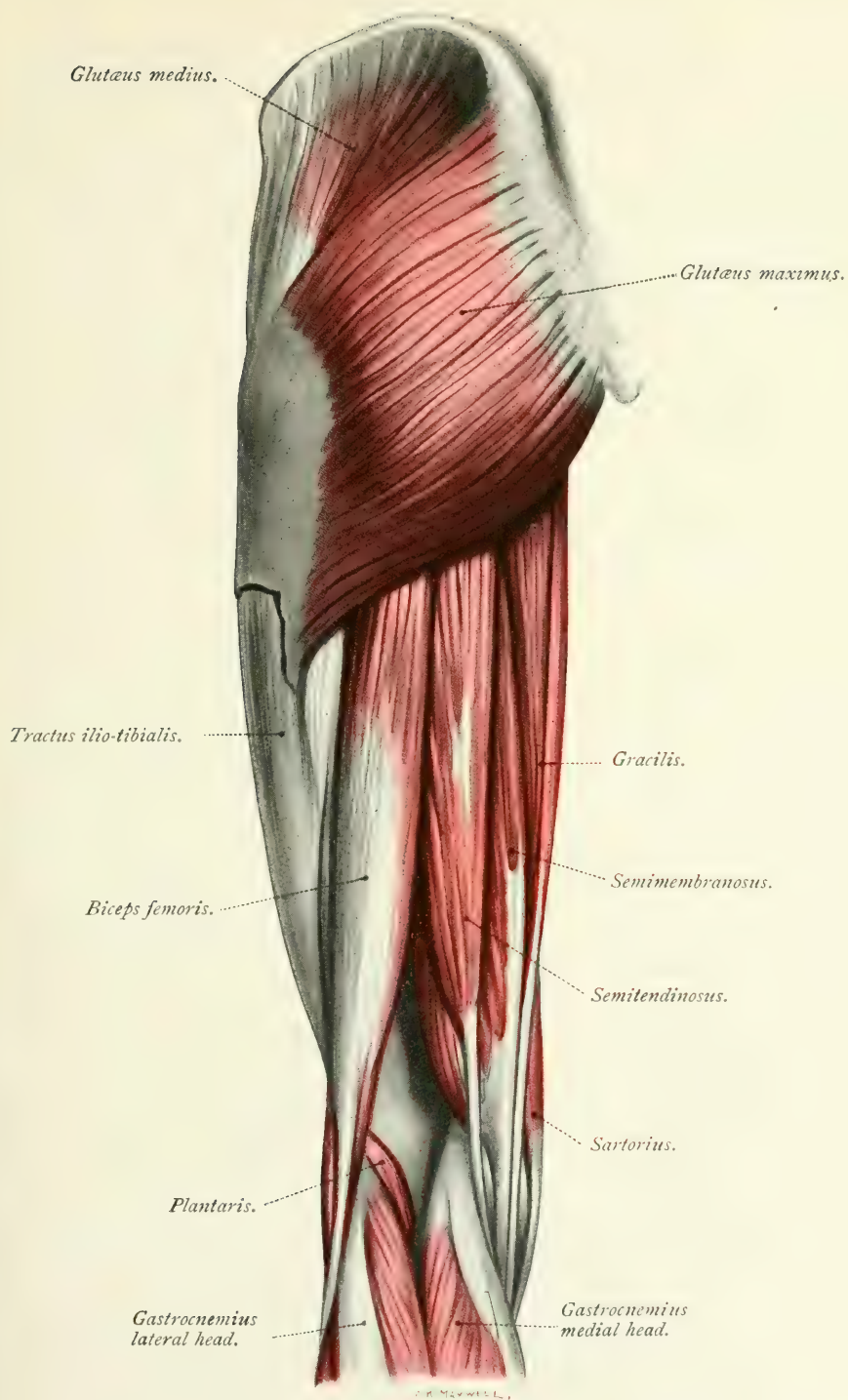


FIG. 77.—THE MUSCLES ON THE BACK OF THE THIGH SEEN IN A SUPERFICIAL DISSECTION.

able quantity of overlying fat, the eminence of the buttock. The fascia on the muscle and the strong septa between its coarse fasciculi are closely connected with the superficial fascia and mass of fat, so that the skin and underlying fascial stratum are not freely movable over the muscle mass as in most other situations. The lower border of the muscle is crossed a little to the lateral side of its middle point by the fold of the nates. The deep surface rests upon the gluteus medius and piriformis muscles, the tendon of the obturator internus with the two gemelli, the quadratus femoris, a small part of the adductor magnus, the greater trochanter, the ischial tuberosity, and the origin of the hamstring muscles. Under cover of the muscles the inferior gluteal vessels emerge from the pelvis below the piriformis while the superficial part of the superior gluteal artery passes out above that muscle. The great sciatic nerve likewise emerges below the piriformis along with the pudendal vessels and nerve which lie behind the ischial spine.

Between the fascial insertion of the muscle and the greater trochanter is a large bursa, which may be replaced by two or three smaller ones; another intervenes between it and the upper part of the vastus lateralis. In some cases there is also a bursa over the ischial tuberosity. A varying number of small bursæ are also found at the bony insertion between the tendinous bundles.

Varieties.—These are not frequent. The muscle has been seen receiving an additional fasciculus of origin from the lumbar aponeurosis, or from the ischial tuberosity. This fasciculus may be independent (*ischio-femoral muscle*). A distinct slip at the lower border arising from the coccyx and attached to the femur represents a caudal head, the *coccygeo-femoral* or *agitator caudæ* muscle, of lower mammals. The fibres arising from the sacro-tuberous ligament and the margin of the sacrum are normally separated by a layer of areolar tissue from the superficial portion; a powerful development of this deep part gives rise to the bilaminar condition which has been described. A very rare but, for theoretical reasons, interesting variation is the fusion more or less complete of the gluteus maximus and tensor fasciæ latæ. The iliac origin is generally wanting in lower mammals.

M. Tensor Fasciæ Latæ (fig. 79, p. 237). The tensor fasciæ latæ is placed along the lateral border of the thigh where the gluteal region passes on to the anterior aspect of the thigh. It lies between the two layers of the fascia described above, *i.e.* the supra-trochanteric part of the ilio-tibial band and the deep process which passes upwards on its medial aspect. It arises by tendinous fibres from the outer margin of the iliac crest at its fore part, from the notch between the two anterior iliac spines external to the attachment of the sartorius, and by some fleshy fibres from the fascia covering the gluteus medius. The muscular belly is prismatic in shape, the posterior surface being related to the gluteus medius with which it is intimately united, and also the vastus lateralis; its medial surface is in relation to the iliacus and rectus tendon, separated from them, however, by the deep fascial septum; its lateral surface is invested by the fascia lata. The fasciculi are parallel to one another and are inserted between the two lamellæ of the fascia from three to four inches below the trochanter major. The tendinous fibres prolonged from this insertion form part of the ilio-tibial band and can be followed in this down to the lateral condyle of the tibia.

The ilio-tibial band, as already stated under the head of the fascia lata, is thus constituted by tendinous fibres derived from the gluteus maximus and tensor fasciæ latæ. Through this system of longitudinal tendinous fibres the two muscles find insertion (1) on the lateral condyle of the tibia, (2) on the patella by the lateral patellar ligament, and (3) on the outer lip of the linea aspera and lateral supra-condylar ridge, through the medium of the so-called lateral intermuscular septum, and its cord-like continuation to the lateral condyle of the femur.

Varieties.—It is occasionally found divided longitudinally, partially or entirely. Accessory slips have been described proceeding from the iliac crest, inguinal ligament, or aponeurosis of the abdominal wall. The tensor fasciæ latæ and gluteus maximus represent separated portions of a muscle known as the *ilio-tibialis* in reptilia. It is more or less bound up with the crural extensor, and constitutes in Iguana an iliac head of origin to that muscle (Rabl.), and is attached with it to patella and tibia. The ilio-tibial band represents the original insertion of the muscle, while the gluteal element has acquired a femoral attachment, or it may be has been combined with a caudo-femoral muscle.

M. Glutæus Medius (fig. 78).—The middle gluteal muscle lies partly under the glutæus maximus, partly under the fascia between this muscle and the tensor fasciæ latæ, and in turn covers the glutæus minimus. It arises from the iliac surface of the hip-bone between the posterior and middle gluteal lines, and from the fascia covering its anterior and upper part. The muscular fibres converge as they descend on to a broad flattened tendon which appears on the deep face of the muscle and is inserted into an impression directed from the postero-superior angle of the trochanter major obliquely downwards and forwards over its lateral face. The muscular fasciculi form two groups: the anterior which pass downwards and backwards, and the posterior which are directed downwards and forwards and reach the tendon by passing deep to the anterior fibres. The fibres along the anterior border which are covered by the tensor fasciæ latæ are parallel, and generally united with those of the glutæus minimus. The posterior border is related to, and often in part united with, the pyriformis, the superior gluteal vessels and nerves passing between them. The tendons of the two muscles are also partly adherent. The tendon is separated from the upper part of the trochanter by one or more small bursæ.

Varieties.—The muscle may be divided into two lamellæ, or the deeper fibres may end on a separate tendon which is inserted into the upper border of the trochanter major. A bursa is occasionally present between the tendon of the muscle and the pyriformis (1 in 15, Macalister).

M. Glutæus Minimus (fig. 80).—Lying under the glutæus medius the glutæus minimus arises from the gluteal surface of the iliac bone between the middle and inferior gluteal lines. The fibres, converging as they descend, terminate in an expanded fascicular tendon which is developed on the outer face of the muscle and becoming narrowed is inserted into an impression on the front of the greater trochanter. The tendon is bound down to the prominence of the trochanter by a strong fibrous band which joins it from the upper margin of the capsule of the hip-joint. A synovial bursa is interposed between the tendon and the trochanter of the femur. The anterior border of the muscle is in contact with that of the glutæus medius and the two muscles are frequently fused. The posterior border is covered by the pyriformis, and fusion may occur here between the muscles. Its deep surface is in contact with the capsule of the hip-joint and the reflected head of the rectus muscle.

Varieties.—In addition to the common fusions already mentioned, detached slips may connect the muscle with the tensor fasciæ latæ, with the superior gemellus, with the upper part of the origin of the vastus lateralis, or with the capsule of the hip-joint. This last may take the form of an accessory muscle under cover of the main mass. The anterior and posterior parts may be separate, or the anterior fibres detached from the rest may form an independent muscle named the *gluteus quartus* or *inverted femoris* (Owen) and *scansorius* in the apes.

M. Pyriformis (fig. 78).—The pyriformis muscle arises within the pelvis by three digitations from the second, third, and fourth pieces of the sacrum between, and lateral to, the anterior sacral foramina. When the muscle is strongly developed it spreads on to the bodies of the vertebræ, and on the second or third there is frequently an arched ridge to show the extent of the attachment of the muscle (Adolphi). The fleshy mass thus formed is inclined outwards, forwards, and a little downwards, and leaves the pelvis at the great sacro-sciatic foramen, receiving as it emerges a few fibres from the hip-bone below the posterior inferior iliac spine and the sacro-tuberous ligament. Here it is in close contact, and often in union with the glutæus medius above and the superior gemellus below. The fleshy belly rapidly narrows as it passes outwards and ends on a rounded tendon which

is inserted into a mark on the upper border of the trochanter major, and is closely united for some distance before its insertion with the subjacent tendon of the obturator internus and gemelli muscles. A bursa is described as occurring between the tendon and the bone.

Relations.—The anterior surface of the pyriformis is in contact, inside the pelvis, with the nerves of the sacral plexus, a thin portion of the pelvic fascia, the anterior branches of the internal iliac vessels, and the rectum; while in the gluteal region it lies over the ischium and the hinder part of the gluteus minimus, by which it is usually separated from the hip-joint. Its posterior surface is covered by the sacrum and the gluteus maximus; and the tendon at its insertion is beneath the gluteus medius, there being occasionally a bursa between the two. Between the upper border of the muscle as it escapes from the pelvis and the bone the gluteal vessels and superior gluteal nerve issue; and at its lower border, between it and the superior gemellus, the sciatic and pudic vessels and nerves make their appearance.

Varieties.—The most frequent variation met with is the division of the muscle into two parts. This is usually associated with a high division of the sciatic nerve, and the peroneal division then emerges through the cleft between the two parts. The cleavage generally affects only the muscular belly, but may involve the whole muscle. Subdivision into several fascicles has also been observed. The absence of the muscle has been recorded, and fusion frequently takes place between it and the gluteus medius, the gluteus minimus, the superior gemellus, or in rare cases even the internal obturator muscle. Its digitations may be reduced to two or increased to four. It may be inserted into the capsule of the hip-joint.

M. Obturator Internus (fig. 78).—The obturator internus is in great part lodged within the pelvis and is remarkable for the way in which its tendon turns at right angles over the border of the hip-bone under the sacro-tuberous ligament to reach its insertion on the greater trochanter. The muscle arises from the deep surface of the obturator membrane except at its lower part, from the fibrous arch which completes the canal for the obturator vessels and nerve, and from the pelvic surface of the hip-bone. The bony origin extends over the area between the obturator foramen and ilio-sciatic notch, reaching the ilio-pectineal line above and the ischial and pubic margins of the obturator foramen below. The fasciculi converge from this extensive origin on the lesser sacro-sciatic foramen from which the muscle emerges. Turning at a sharp angle round the bone the muscle is then directed outwards to be inserted in connexion with the gemelli into an impression on the fore part of the medial surface of the trochanter major. The tendon occupies the face of the muscle which is turned towards the bone, and consists of four or five narrow portions, which, commencing independently in the substance of the pelvic portion of the muscle, receive the pennately disposed fleshy fibres. The surface of the bone in the notch over which the tendon plays, as over a pulley, is covered by a layer of cartilage, and this is grooved for the divisions of the tendon. The gliding of the tendon on the bone is further facilitated by a large synovial bursa which invests the tendon and sends processes between its divisions and sometimes extensions between the gemelli and the tendon. The tendon is hidden from view by the fleshy fibres of the muscle and of the separate slips known as the gemelli, and to display the arrangements described it is necessary to cut the tendon near its insertion and draw it inwards. Another bursa of much smaller size than the main sac, with which it occasionally communicates, is sometimes placed between the tendon and the hip-joint near its insertion.

Mm. Gemelli (fig. 78).—These little muscles may be regarded as detached portions of the obturator internus arising outside the pelvis. They are small, narrow slips of fleshy fibres placed on each side of the tendon of that muscle, and are named from their position above and below the tendon. The *gemellus superior*, usually the smaller of the two, arises from the outer and lower part of the ischial spine; the *gemellus inferior* takes origin from the upper part of the tuberosity

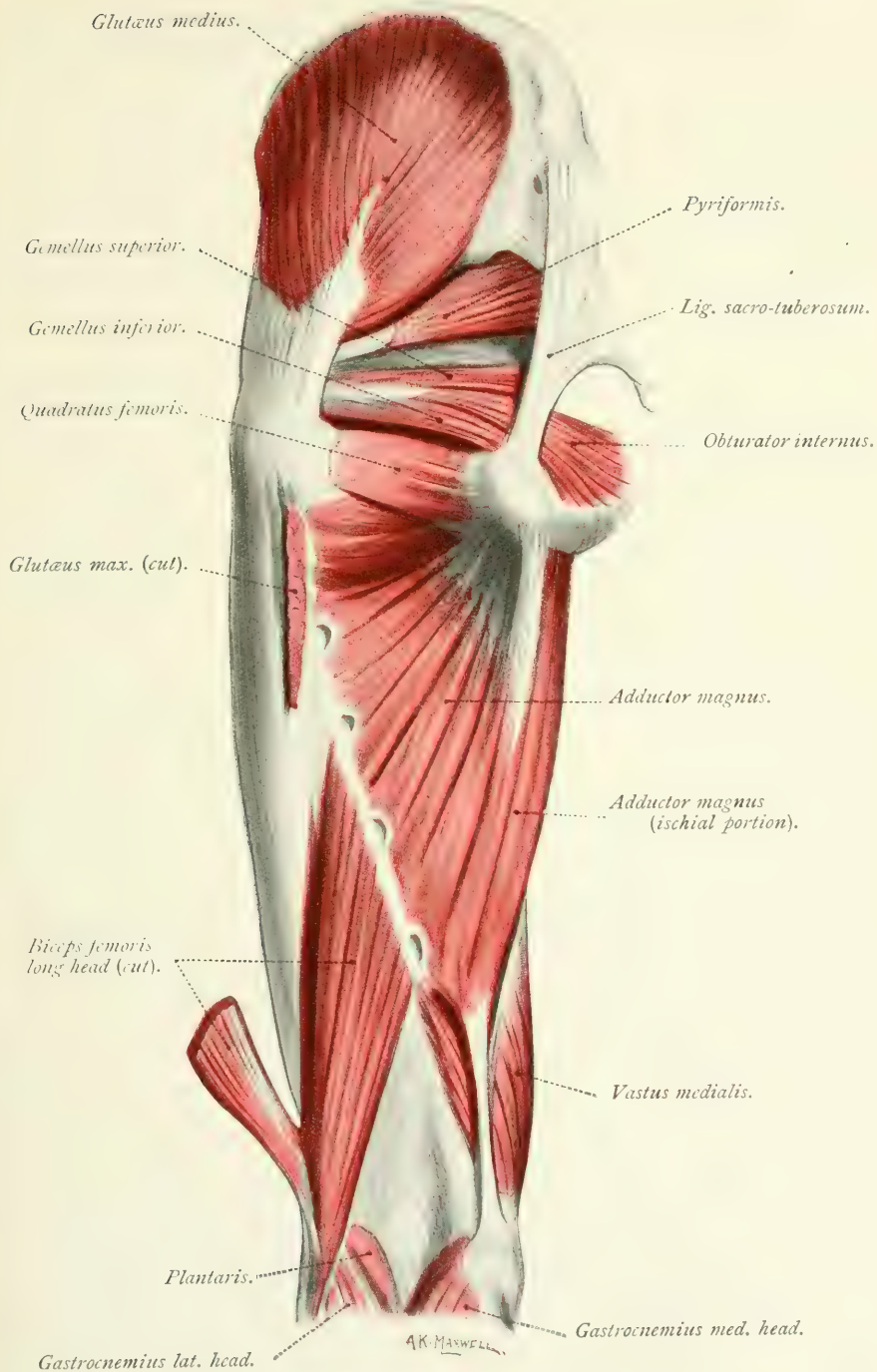


FIG. 78.—THE DEEP MUSCLES OF THE GLUTEAL REGION AND OF THE BACK OF THE THIGH.

along the lower border of the groove for the obturator internus. Passing outwards, they join the tendon of the obturator internus muscle, and are inserted with it into the great trochanter. The two muscles usually meet at their origin below the tendon of the obturator, while at their insertion they overlap and more or less conceal it. The superior gemellus is placed immediately below the piriformis, the inferior is in contact with the quadratus femoris muscle.

Varieties.—The obturator internus muscle is not subject to much variation. Cases have been observed in which it is partly or completely divided into two parts, and various accessory slips have been noted. The gemelli vary in size, the superior being small and not infrequently absent altogether. Absence of the inferior gemellus has also been noted but more rarely than that of the upper muscle. The superior gemellus may be fused with the piriformis or gluteus minimus, the inferior with the quadratus femoris. Both are very frequently more or less continuous with the obturator internus.

M. Quadratus Femoris (fig. 78).—As its name implies this muscle has the form of a rectangular mass which extends transversely from the ischial tuberosity to the femur under the gluteus maximus, in the interval between the inferior gemellus and adductor magnus. It arises from the outer border of the ischial tuberosity, and is inserted into the quadratus tubercle and a rough line leading from this on the posterior aspect of the femur reaching to the level of the trochanter minor. The muscle covers the tendon of the obturator externus and the accompanying ascending branch of the medial circumflex artery, and there is generally a bursa between it and the lesser trochanter.

Varieties.—The muscle may be fused with the inferior gemellus or adductor magnus, may be replaced by a large inferior gemellus, or may be absent altogether. It may be divided at its femoral insertion into two parts, one posterior with the normal attachment, the second anterior inserted into the intertrochanteric crest. In cases such as this there is frequently a bursa between the two layers of the muscle.

The obturator externus muscle belongs to the adductor group of muscles and will be described along with them, although from the point of view of its part-action as external rotator it is generally described along with the muscles of the gluteal region.

Nerve Supply of the Gluteal Group of Muscles.—The *gluteus maximus* is supplied by the inferior gluteal nerve (5L, 1, and 2S), the *gluteus medius* and *minimus* and *tensor fasciæ latæ* by the superior gluteal nerve (4 and 5L, 1S). The nerve to the gluteus maximus emerges from the pelvis below the piriformis muscle. It breaks up fanwise into five or more branches which enter the deep surface of the muscle in its lower half about 5 cm. from the middle line. The proximal branches of distribution in the muscle are thus longer than the distal. The superior gluteal nerve emerges above the piriformis muscle, and lies between the gluteus medius and minimus supplying the first from its deep, the second from its superficial aspect. Two branches are given off; the first ends in the gluteus medius and breaks up into several branches before it enters the muscle; the second supplies the gluteus minimus and tensor fasciæ latæ. This second branch comes off the superior gluteal trunk either in the sacro-sciatic foramen or as it lies between the muscles. It supplies the minimus, and gives off about the middle of this muscle the nerve to the tensor fasciæ, which courses forward between the gluteus medius and minimus to reach its muscle on its deep surface in its proximal third below the anterior superior iliac spine. The *piriformis* muscle develops within the pelvis and is supplied direct by branches from the first and second sacral nerves and, it may be, also from the third sacral and last lumbar nerves. The *obturator internus* develops in connexion with the ischial bone and secondarily spreads over the inner wall of the pelvis. Its nerve which springs from the sacral plexus (5L, 1, and 2S) emerges through the greater sacro-sciatic foramen, but is carried into the pelvis again along with the spreading muscle rudiment. It is found in the adult, therefore, re-entering the pelvis through the lesser sacro-sciatic foramen to reach the belly of its muscle. It drops by the way a twig to the *superior gemellus*; also the extra-pelvic portion of the obturator internus is supplied by a special branch which is generally bound up with the nerve to the quadratus, but may arise separately. The nerve to the superior gemellus may also come from the nerve to the *quadratus femoris* (4, 5L, 1S). This last reaches the deep surface of its muscle by passing, after it has emerged from the great sacro-sciatic foramen, under the gemelli and tendon of the obturator internus and gives a branch to the *inferior gemellus*.

TABLE V.—ACTIONS OF THE MUSCLES OF THE HIP-JOINT

	Flexion.	Extension.	Abduction.	Adduction.	Med. Rot.	Lat. Rot.
Glut. max. - - -	...	+ (1)	...	+ (2)	...	+ (1)
„ med. - - -	...	+ (6)	+ (1)	...	+ (1)	...
„ min. - - -	+ (9)	...	+ (2)	...	+ (2)	...
Pyriformis - - -	...	+ (7)	+ (3)	...	...	+ (4)
Obturator inter. - -	...	+ (8)	...	} + (11) {	...	+ (3)
Gemelli - - -	...	...	...		...	...
Quadratus fem. - -	+ (12)	...	...	+ (5)	...	+ (2)
Adductor mag. - -	+ (10)	+ (2)	...	(1)	+ (4)	+ (7)
„ longus - - -	+ (3)	...	...	+ (4)	+ (6)	...
„ brevis - - -	+ (4)	...	...	+ (3)	...	+ (6)
Gracilis - - -	+ (11)	...	...	...	...	+ (11)
Pectineus - - -	+ (7)	...	...	+ (8)	+ (5)	...
Rectus fem. - - -	+ (2)	...	+ (4)	...	...	+ (5)
Psoas and iliacus - -	+ (1)	...	...	...	+ (3)	...
Tens. fasc. fem. - -	+ (6)	...	+ (5)	...	...	+ (12)
Semitendinous - - -	...	+ (4)	...	+ (10)	+ (7)	...
Semimembranosus - -	...	+ (5)	...	+ (12)	+ (8)	...
Biceps - - -	...	+ (3)	...	+ (9)	...	+ (8)
Obtur. exter. - - -	+ (5)	...	...	+ (6)	...	+ (10)
Sartorius - - -	+ (8)	...	+ (6)	+ (7)	...	+ (9)

Compiled from various sources: the popliteus is not reckoned as a femoral muscle. The numbers indicate the relative power-values of the different muscles.

Action of the Muscles which Operate on the Hip-Joint.—The primary movements at the hip-joint are flexion and extension of the thigh, and abduction and adduction and lateral and medial rotation of the limb as a whole. The latter movements are not ordinarily performed alone but are usually associated with movements of flexion and extension. In the ordinary movements of walking they are normal accompaniments of flexion and extension, but are reversed, the trunk moving on the thighs; the same muscles, of course, effect the displacements. These more secondary movements may, however, be performed alone, while a compound movement of circumduction is also possible. The muscles acting on the joint naturally fall into groups producing the primary movements, for each of which, except the movement of medial rotation, there may be said to be a special group of muscles; they may therefore be grouped as extensors, flexors, adductors, abductors, and rotators. Within each group each muscle may have secondary accompaniments of its main action, and different parts of the same muscle may have different secondary actions (Table V.). Thus it will be found that, in the same group of muscles, the secondary accompaniments of muscles which have the same primary action are not alike. There must always be, therefore, a very distinct selective grouping of muscles, or even parts of muscles, acting at one time to ensure the ordinary movements of a spheroidal joint like the hip (see p. 12).

The extensor muscles are more powerful than the flexors in the proportion of about 6 to 5, a preponderance of extensors over flexors which is characteristic only of the human subject. The lateral rotators are three times more powerful than the medial rotators and the adductors are much more powerful than the abductors.

The reciprocal action of the muscles of the hip should always be borne in mind: that is, that while the thigh is the moving part when the trunk is fixed, the trunk will be the moving part if the lower limbs are fixed, as in standing erect on both extended legs.

The glutæus maximus serves to extend the femur on the pelvis, that is, to draw it backwards. It so acts with all its fibres, and since these are so arranged that the anatomical transverse section practically corresponds to the physiological section—a human characteristic—it is a most powerful muscle. Through its attachment to the fascia lata the action of the muscle is extended over the whole length of the thigh and, further, it is enabled to exercise an influence upon the knee-joint, steadying and supporting that joint in the extended position when the proper extensor muscles are relaxed. In ordinary walking movements the glutæus maximus is not used to any great extent (since the flexion movement is the more active movement in walking), but in quicker and in forcible movements and in rising from the sitting to the standing position, the muscle acts with

great power. In paralysis of this muscle, therefore, ordinary movements are not greatly hindered. Nor is the contraction of the muscle necessary for the maintenance of the erect position of the body, since the line of gravity falls behind the transverse axis of the hip-joints. The greater part of the muscle also acts as an adductor and lateral rotator of the thigh, the upper anterior part alone being capable of producing abduction and medial rotation if no medial rotation is already present. The *glutæus maximus* may not only extend the femur on the pelvis, but reciprocally may extend the pelvis on the thighs, when the body has been bent forwards in the standing position. The attachment to the coccyx, older writers emphasised, may serve to bring that bone forwards and hinder it from being thrust too far backwards "in the excretion of hardened feces or in difficult births" (Winslow).

The *glutæus medius* and *minimus* are, in the main, muscles of abduction; the *minimus* in fact has almost no other action. Their action is most evident in that part of the movement of walking when the body is supported on one leg, for then they tilt the pelvis over the supporting limb and prevent it falling to the opposite side. The *glutæus maximus* takes little, if any part, in this movement. The anterior part of the *glutæus medius* may act as a flexor and medial rotator and the posterior part as an extensor and lateral rotator. The sagittal action is probably of little account, but the medial rotatory action probably comes into play when the legs are crossed in the sitting position. By successive faradisation of the *glutæus medius* from before backwards Duchenne produced a movement of circumduction of the limb. The *glutæus minimus* may probably act slightly as a flexor.

The position of the tensor fasciæ latæ and the direction of its fibres would indicate that it is a flexor of the thigh, and that it might also act, in most positions, as an abductor and medial rotator. While the muscle may act with the *ilio-psoas* as a flexor in walking, its chief action is probably to correct the obliquity of the pull of the *glutæus maximus* on the *ilio-tibial* band and to ensure a greater precision in the action of that muscle. The action on the *ilio-tibial* band has also been described as preventing the displacement of the *vastus lateralis*.

The small *pelvo-trochanteric* muscles of the gluteal region—the *pyriformis*, *obturator internus*, *gemelli*, *quadratus femoris*, and *obturator externus*—are lateral rotators of the femur, or if they act from the femur, as in standing on one leg, they will rotate the pelvis to the opposite side. In the position of flexion, however, they act as abductors, and the capsular connexions of most of them serve to prevent the falling in of the capsule which might otherwise occur (Winslow).

The *ilio-psoas* muscle is a flexor of the thigh and by far the most powerful of all the flexors. In semiflexion, the axis of the tendon is perpendicular to the axis of the femur, and consequently it then acts with greatest power. The traction exercised by the common tendon is practically directly forwards, but the *ilio-psoas* is said to have a slight lateral rotation action, and this is probably so in most positions; Fick, however, describes it as a medial rotator. If the thighs are fixed, the muscles of the two sides acting together will draw forwards the lumbar vertebrae and the pelvis; if one muscle acts alone the pelvis will be rotated to the opposite side.

The three adductor muscles, *longus*, *brevis*, and *magnus*, with the *pectineus* as a weak accessory, move the thigh medialwards. They are used, therefore, in all the movements in which the thighs are pressed together, and in walking they act with their opponents, the *glutæus medius* and *minimus*, to balance the trunk on the supporting limb. The muscles of adduction are extremely powerful, the sum of their moments of contraction exceeding even that of the extensors; and it should be noted how wide is their origin from the pelvis and how long is the distribution of their insertion on the femur. The significance of the difference in the planes of attachment has already been pointed out (p. 8); it is such that the adductors can act powerfully at all degrees of flexion. The uppermost parts of the adductor mass, the *pectineus* especially, but also the adductors *longus* and *brevis*, have considerable power of flexion, and to a small extent of lateral rotation, while the lowermost part of the adductor *magnus* is an extensor.

The other muscles which act at the hip-joint also act at the knee. The *rectus femoris* is an almost pure flexor and a powerful adjunct to the *ilio-psoas*. According to Ross it is the usual muscle employed in ordinary flexion movements, "for after amputation through the middle of the femur the stump is not flexed during the first few days." It acts mainly from the straight head when the thigh is extended and from the reflected head when the thigh is flexed. It may have a slight medial rotatory action. The *sartorius* acts as a flexor of the hip, and does so with considerable force since it is well removed from the centre of motion. It is also a weak abductor and lateral rotator, but in itself cannot produce the "tailor position" of the limb. The *gracilis* is chiefly an adductor at the hip; it has very little flexion action. The hamstring muscles are extensors at the hip, and the more the hip is flexed the stronger they act. At all times, however, the state of the knee-joint influences the amount of their action at the hip; and it has already been shown (p. 14) how they limit flexion at the hip if the knee-joint remains extended. They may also act as weak adductors at the hip.

THE MUSCLES OF THE THIGH

The muscles of the thigh are, according to position and nerve supply, arranged in three distinct groups:—

I. *The muscles on the front of the thigh supplied by the femoral nerve.* This group includes (1) the *quadriceps femoris*, which is again subdivided into a superficial mass extending over two joints and with no attachment to the femur, viz. the *rectus femoris* muscle, and a deep system of muscles embracing the three *vasti muscles* which are attached to the femur and act on the knee-joint alone. (2) The *sartorius*, which in virtue of its course and position is a flexor of the knee and hip.

II. *The muscles on the medial side of the thigh supplied by the obturator nerve.* Essentially adductors, this group embraces the *pectineus*, *adductores gracilis*, *longus*, *brevis*, *magnus*, and the *obturator externus*.

III. *The muscles on the back of the leg supplied by the great sciatic nerve.* Chiefly flexors of the knee but acting over two joints, they are named the *biceps femoris*, *semitendinosus* and *semimembranosus*.

It will be convenient to take the last group first, as it naturally follows on the series of muscles last described.

The Posterior Femoral or Hamstring Muscles

M. Biceps Flexor Cruris, or Biceps Femoris (figs. 77, 78, 85).—The biceps of the leg consists of two parts, arising one from the hip-bone and one from the femur, which unite distally on a common tendon attached to the head of the fibula. The *long head* arises by a tendon common to it and the semitendinosus from the inner impression on the upper part of the ischial tuberosity, receiving some fibres also from the sacro-tuberous ligament. The muscular fasciculi, which begin to spring from the lateral aspect of the tendon a short distance below the tuberosity, form a prismatic belly which inclines lateralwards and ends on a flattened tendon which appears on the posterior aspect of the muscle about the middle of the thigh. The *short head* arises from the lateral lip of the linea aspera in its whole extent, from the lateral supracondylar line, and from the lateral intermuscular septum. Its muscular fasciculi are short and oblique and extend backwards to end on the anterior face of the flat tendon above referred to. This tendon contracts to form a rounded cord which, becoming free of muscular fibres about the level of the knee-joint, is inserted into the lateral and proximal part of the head of the fibula by two portions which embrace the fibular collateral ligament of the knee-joint. Some of the fibres of the tendon, passing forwards and medially, are inserted into the lateral condyle of the tibia, and from the posterior border others are given off to the fascia of the leg. A bursa is generally present between the tendon and the collateral ligament, and there is sometimes another between the long head and the origin of the semimembranosus.

Varieties.—There are good reasons for concluding that the two portions of the biceps really represent two separate muscles which have been united together in man. In rare cases they remain apart either partially or entirely, or the short head may even be wanting. In the orang-outang the two portions are separate, but in the chimpanzee and gorilla they are partially united. The normal attachment to the crural fascia represents an extension to the leg seen in lower mammals or the *ilio-peroneal muscle* of lower terrestrial vertebrates, and this crural extension is reproduced in various instances recorded, in which muscular slips were found attached to the fascia (*tensor fasciæ suralis*), to the gastrocnemius or tendo Achillis. Accessory slips have been noted derived from various sources such as the sacrum, coccyx, sacro-tuberous ligament, ischial tuberosity,

gluteus maximus, gluteal ridge of femur or linea aspera at its upper extremity, the fascia lata, gastrocnemius and lateral condyle of femur, adductor magnus or vastus lateralis

In the lower vertebrates the long portion of the muscle is attached to the iliac bone, and further in lower forms there is a coccygeal head. The suggestion has been made, therefore, that the sacro-tuberous ligament represents the primitive proximal extension of the muscle to these parts.

The short head, entirely wanting in some lower mammals or present only as an independent muscle in others, has close relations with the gluteus maximus and therefore also with the tensor fasciæ latæ. These muscles together seem to represent a lateral crural muscle which has in great part become aponeurotic. This theory is supported by the following considerations: 1st, in development the short head of the biceps is a distal continuation of the muscle mass which gives origin to the gluteus maximus; 2nd, the nerve of supply comes off the peroneal division of the great sciatic nerve high up in the thigh, and cases have been noted in which it arises from the sacral plexus in common with the inferior gluteal nerve.

M. Semitendinosus (figs. 77, 83, 84). Closely united at its origin with the long head of the biceps, the semitendinosus muscle arises by fleshy fibres from the ischial tuberosity and from the medial side of the common tendon for about three inches or more. The belly is flattened from before backwards at first, but soon becomes rounded and then narrowing, ends in the lower third of the thigh upon a long rounded and slender tendon. This appears on the inner face of the muscle as a flattened band about the middle of the thigh and proceeds downwards on the semimembranosus along the medial side of the popliteal space. It then passes behind the medial femoral condyle, and finally below the medial tibial condyle curves forwards to be inserted in expanded form into the proximal part of the medial surface of the tibia, a considerable process being sent from its lower border to the fascia of the leg. At its insertion the tendon is on the same plane with but below that of the gracilis, both being under cover of the sartorius, and a bursa separates the three tendons from the tibial collateral ligament of the knee-joint. The belly of the muscle is traversed about its middle by a thin oblique tendinous intersection.

Varieties.—The independence of the semitendinosus from the biceps has been noted, a condition which is of interest in view of the fact that the two muscles are independent in lower vertebrate forms. The muscle is sometimes found in part fused with the semimembranosus, and cases have been noted in which the biceps and semitendinosus were joined by a muscular slip. Accessory slips have been observed arising from the coccyx, the sacro-tuberous ligament, or the ischial tuberosity, and joining the belly of the muscle. A rare variety is one in which a slip arises from the linea aspera below the semitendinosus and ends on the medial condyle and back of the knee-joint. The fascial insertion represents the more extensive crural insertion found in lower mammals. The name *tensor fasciæ suralis* or *ischioaponeuroticus* has been given to a slip which, leaving the belly of the semitendinosus, or it may be one of the other hamstrings, ends on a tendon which joins the fascia of the leg.

M. Semimembranosus (figs. 77, 83, 84, 85).—The semimembranosus muscle arises from the ischial tuberosity, proximal to, and on the lateral side of, the common origin of the biceps and semitendinosus, by a broad flattened tendon which is grooved on its posterior face for the reception of the common tendon of these two muscles. The tendon of origin is prolonged downwards on the lateral side of the muscle for three-fourths of the length of the thigh. From it spring short fleshy fasciculi which are directed obliquely downwards and medially, forming a thick fusiform belly, to end upon a tendon of insertion which occupies the opposite border of the muscle. The lower tendon appears about the middle of the thigh on the anterior face and on the medial border of the muscle, and becoming free of muscular fibres at the level of the knee-joint forms a thick flat cord which has a threefold insertion as follows: (1) Into the horizontal groove on the back of the medial condyle of the tibia extending forwards under the medial collateral ligament of the joint; (2) into the fascia over the popliteus by superficial fibres which continue directly the line of the main tendon; (3) by a strong expansion of fibres

which turn upwards and lateralwards to the posterior ligament of the joint. There is a small synovial bursa between the main part of the tendon and the prominent proximal margin of the groove on the tibia, and between the lower tendon and the medial head of the gastrocnemius there is a large bursa which often communicates with the cavity of the knee-joint. A small bursa occurs also between the tendon of origin and the tendon of the biceps.

Varieties.—Considerable reduction and even complete absence of the semimembranosus have been observed. It may be duplicated, or rather split along its length. The second belly may have the form of a small fleshy slip with proximal and distal tendons or may arise from the sacrotuberous ligament. The distal tendon is inserted in various ways. In one case of the kind which occurred in the writer's department it was observed to be attached by one slip to the main tendon with a larger slip to the oblique popliteal ligament, and a delicate reflected slip inserted on to the medial supracondylar ridge. Sometimes the tendon joins that of the adductor magnus. Partial fusion with the semitendinosus was mentioned under the head of that muscle. As in the case of the other hamstrings extension of the proximal attachments to the coccyx has been noted.

Relations of the Hamstring Muscles. The hamstring muscles at their origin are under cover of the gluteus maximus. The common tendon of the biceps and semitendinosus lies behind, or superficial to, that of the semimembranosus which is grooved for its reception. Below the distal border of the gluteus maximus, the biceps and semitendinosus descend side by side under the skin, while the semimembranosus occupies a deeper position. All three muscles are in contact with one another, being bound down by the fascia lata, but inferiorly they diverge, the biceps passing to the lateral, the other two muscles to the medial side of the knee-joint, forming the upper lateral boundaries of the lozenge-shaped *popliteal space*, the infero-lateral boundaries of which are formed by the heads of the gastrocnemius muscle.

The biceps muscle lies towards the lateral aspect of the thigh and it rests on the semimembranosus, the adductor magnus, the vastus lateralis, from which it is separated, however, by the lateral intermuscular septum, and lastly the origin of the lateral head of the gastrocnemius and plantaris muscles. Its medial border is applied to the semitendinosus and lower down to the semimembranosus. This last muscle, after crossing obliquely from without inwards under cover of the conjoined tendon of the biceps and semitendinosus, is in contact superficially in its whole length with the semitendinosus and rests by its deep surface upon the adductor magnus. The great sciatic nerve crosses very obliquely the deep face of the biceps muscle and lies along the lateral border of the semimembranosus. The lateral popliteal division of the nerve follows closely the tendon of the biceps to the head of the fibula.

Nerves to the Hamstring Group of Muscles. All these muscles are supplied from the great sciatic nerve. The branches to the semi-membranosus, semitendinosus, and long head of the biceps come from the medial popliteal or tibial division of the nerve trunk, that for the short head of the biceps from the lateral popliteal or peroneal division. This last branch comes off the lateral side of the sciatic nerve above the middle of the thigh, and divides up into several branches which enter the muscle along a hilum of considerable extent. It has been observed arising higher up, and even from the sacral plexus direct in common with the inferior gluteal nerve. The morphological significance of this has already been referred to. The nerve to the long head comes off high up, and dividing up enters the muscle a little distal to the gluteal fold. The semitendinosus receives two nerves, one for the upper and one for the lower portion of its belly. The nerve to the semimembranosus comes off, like the nerve to the semitendinosus, just below the ischial tuberosity and divides into a number of branches, which enter the lateral face of the muscle. The lowest branch is still extramuscular down to the lower third of the thigh.

The Anterior Muscles of the Thigh

M. Sartorius (figs. 79, 80, 84).—The sartorius muscle is remarkable for the great length of its fasciculi, and for the spiral course it takes over the front of the thigh. It arises by a short tendon from the anterior superior iliac spine and from a small part of the anterior margin of the iliac bone immediately below. The fleshy belly is very long, narrow and ribbon-shaped, and is covered only by the fascia and integument throughout its whole length. It is directed obliquely inwards over the front of the thigh in the proximal half, and then, having twisted upon itself, passes nearly vertically downwards on the medial aspect of the limb

as far as the knee-joint. Here the fleshy fibres end upon a flat tendon which, turning forwards round the posterior part of the medial surface of the medial condyle of the femur, and expanding into a thin aponeurosis, is inserted into a slight roughness on the medial surface of the tibia near the tuberosity. From the upper border of the tendon an expansion passes to the capsule of the knee-joint, while another expansion extends from the lower border to the fascia of the leg. The tendon covers those of the gracilis and semitendinosus but is separated from them by a bursa, which is generally a prolongation of that between these tendons and the medial collateral ligament of the knee-joint.

Relations.—The muscle in its course distalwards passes over the iliacus, rectus femoris, the femoral vessels and nerve, the pectineus, the adductor longus, adductor magnus, and vastus medialis muscles. The medial border of the muscle in its proximal part, and the most projecting part of the adductor longus, form the sides, and the inguinal ligament the base of a triangular space in the upper third of the thigh through the middle of which the femoral artery passes. This is named the *femoral triangle* or *triangle of Scarpa*. Below the apex of this triangle formed by the crossing of the sartorius over the border of the adductor longus, the muscle covers and conceals the *Canal of Hunter*.

Varieties.—The sartorius in virtue of its position is a flexor of the knee-joint, but this is a secondary adaptation. In its primitive form it is an extensor. Originally it had a pubic attachment and in certain mammals a second pelvic head is a constant feature. In early stages of development in man it is larger than the quadriceps extensor, and in lower mammals it is, as a rule, a relatively larger muscle than it is in man. Its absence has been noted, and this seems a normal thing in the Cheiroptera. The muscle has, in rare cases, been found divided completely into two parts similarly attached; or the accessory portion may be inserted into the fascia lata, the femur above the medial condyle, the ligament of the patella, the tendon of the semitendinosus, or the tendon of the normal portion in which case the muscle seems divided in its middle part. Separate or accessory heads of origin occasionally arise from the notch below the anterior superior iliac spine, the ilio-pectineal line, the pubic bone close to the symphysis, or the inguinal ligament. The tendon of insertion has been found to end in the fascia lata, in the capsule of the knee-joint, and in the fascia of the leg. A tendinous intersection has been seen in rare cases.

M. Quadriceps Extensor Cruris (figs. 79, 80).—The quadriceps extensor of the knee is the largest and one of the most powerful muscles in the body. As its name indicates it consists of four parts to which special names are given, not as heads but as separate muscles. One of these, the rectus femoris, is attached to the hip-bone, and is distinct down to the distal tendon of the muscle. The other three, crureus (vastus intermedius), vastus medialis, and vastus lateralis, are more closely united and arise from the femur, the shaft of which they almost entirely cover. The quadriceps develops from a rudiment which is at first single, but soon differentiates into its four portions.

For the proper appreciation of the arrangement of the parts of this great combination, it is necessary to bear in mind that it is concerned not only in extending the free crus at the knee-joint but in extending the thigh upon the fixed crus. As this reversed action, when the foot is fixed on the ground, necessarily involves the raising or moving of the whole weight of the trunk, the muscle must be of great strength.

(a) The **rectus femoris** (fig. 79) occupies a position superficial to the other portions of the quadriceps muscle, and extends in a straight line down the middle of the thigh from pelvis to patella. It is spindle-shaped and flattened from before backwards, having a central fleshy belly and two long and stout tendons, one at either end. The proximal tendon is attached to the hip-bone by two tendinous heads. One of these, the anterior or *straight* head, is attached to the anterior inferior iliac spine, the other posterior or *reflected* head to an impression on the outer face of the bone immediately above the acetabulum, in close association with the capsule of the hip-joint from which it receives some fibres. The two

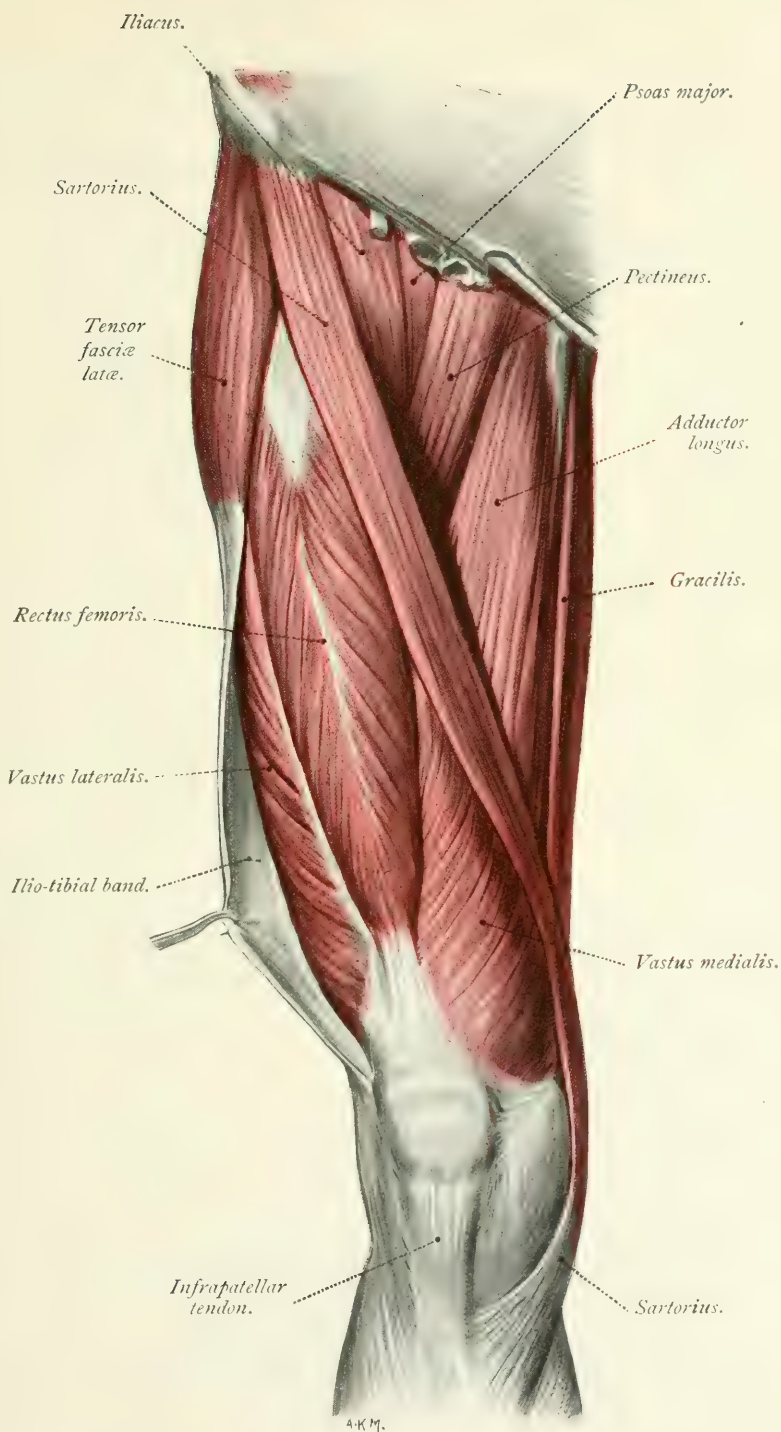


FIG. 79.—MUSCLES ON THE FRONT OF THE THIGH, SUPERFICIAL DISSECTION.

heads join one another at an angle of about 60° close below the margin of the acetabulum, and form a tendon which, widening out, is prolonged on the *anterior* face, and then in the centre of the muscular mass, to beyond the middle of the thigh. From this the fleshy fibres spring pennately, and, passing downwards and backwards as they diverge, they end on the distal tendon, which extends over the lower two-thirds of the *posterior* surface of the belly. This tendon becomes free about three inches above the patella and forms a flat band which is attached to the upper border of that bone, being joined with the tendons of the deeper portions of the quadriceps, and forming with them the common tendon of insertion.

According to the view advanced many years ago by W. R. Williams, the reflected head of the rectus is the main tendon and the straight head is a secondary attachment formed by the fascial investment, and appears only in the last months of fetal life. This appears to be correct so far as it goes, but the view based on comparative anatomy, put forward by Le Double, gives a more satisfactory explanation, viz. that the tendon, originally single, has become subdivided owing to the spread of the tendon on the bone and its subsequent separation into two heads, in consequence of the greater development and separation from the acetabular margin of the anterior inferior spine. In some lower mammals (dog, cat, hyæna, and lower primates) the two heads are joined into one, in others there is only a single tendon which represents the reflected head. In man the reflected head may be absent or there may be an additional origin from the anterior superior spine. A few cases have been described in which an accessory slip was found passing from the cotyloid margin down to the aponeurosis of the vastus lateralis.

(b) The **vastus lateralis** (fig. 80) has a narrow origin from the femur, along the upper half of the intertrochanteric line, the fore and outer part of the trochanter major, the outer side of the gluteal ridge, and the proximal half of the linea aspera, and to a slight extent from the lateral intermuscular septum. The origin takes place for the most part by a strong aponeurosis which extends over the outer face of the muscle for the upper two-thirds of its length. From this aponeurosis almost all the fleshy fibres arise, but some deeper ones spring also from the bone immediately beneath it. The muscular fasciculi are directed downwards and forwards round the femur to end upon the aponeurosis of insertion. This occupies the deep surface and anterior border of the mass in its lower half, and is continued down to the outer part of the upper border of the patella joining the other portions of the common tendon, and sending an expansion downwards to the capsule of the knee-joint. A few of the superficial fibres join the lateral border of the rectus tendon, and its deep surface is connected to a greater or less extent with the sub-jacent crureus, especially in its lower part.

The remaining portion of the muscle, viz. the vastus medialis and crureus, appears at first sight to be inseparably united and to form one mass. The separation into two portions is regarded by some anatomists as being purely artificial, and it must be admitted that superficially the fleshy fibres are usually quite continuous above. Below, however, just above the patella, a narrow interval comes into view when the rectus tendon is pulled well downwards, and this can be followed up between the two tendons in the direction of a line from the medial part of the patella to the lower end of the intertrochanteric line of the femur. The two portions can thus be separated from one another.

(c) The **vastus medialis** (figs. 79, 80), like the vastus lateralis, has a long narrow origin from the femur by a superficial aponeurosis and deeper fleshy fibres along the spiral line, and the medial lip of the linea aspera, and medial supracondylar line, while in the lower half fibres also arise from the tendons of the adductor longus and magnus. The origin of the vastus medialis is separated from that of the crureus by an area on the medial aspect of the shaft of the femur which has no muscular fasciculi attached to it. It is this fact which justifies the separate description of the muscle from that of the crureus. The muscular fibres

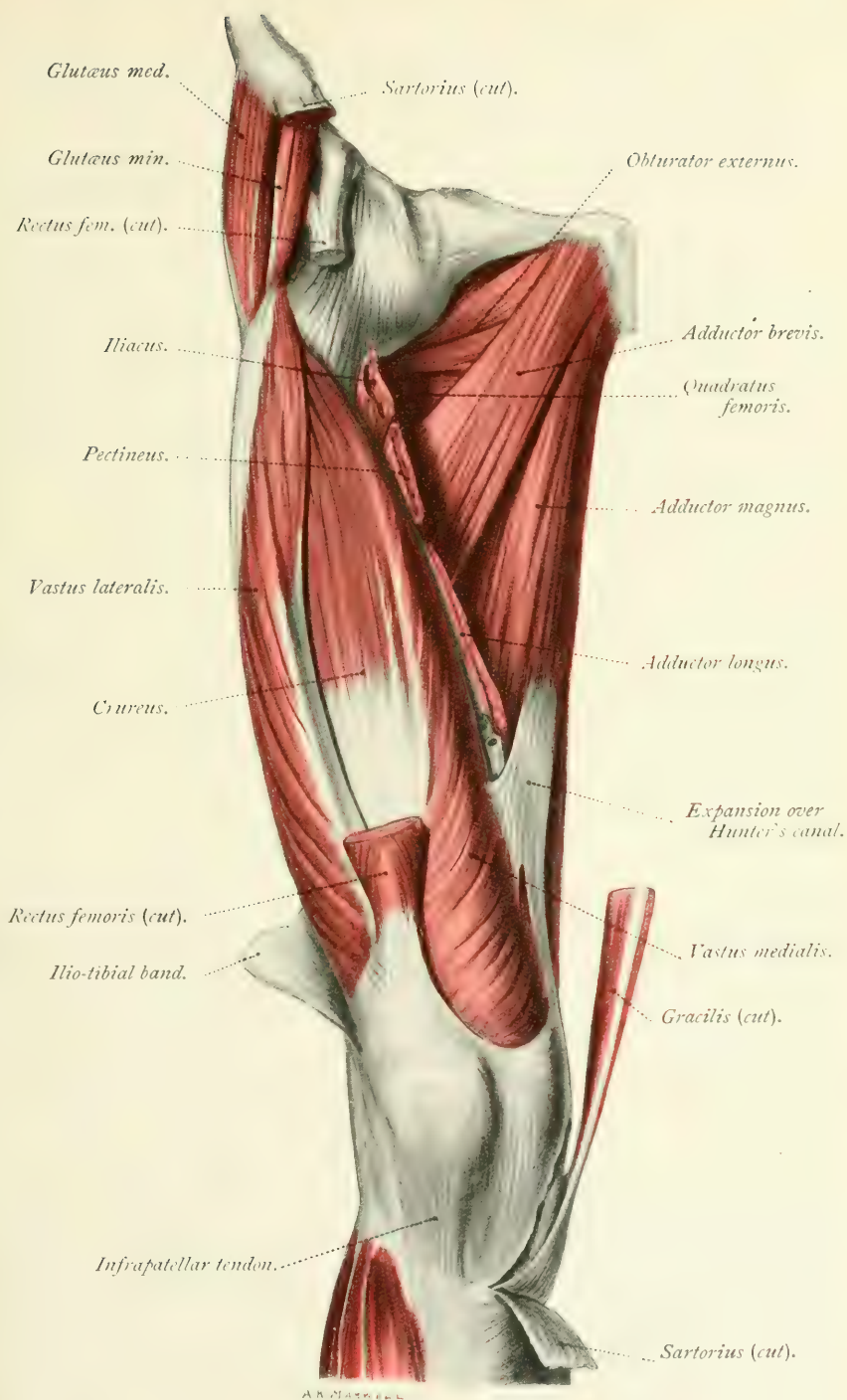


FIG. 80.—MUSCLES ON THE FRONT OF THE THIGH; DEEP DISSECTION. The sartorius, gracilis, iliacus, pectineus, adductor longus and rectus have been cut through and turned aside to show the deeper muscles.

are directed downwards and forwards and end mostly on an aponeurosis which is developed in the interior of the muscle, and forms below, the medial part of the common tendon. The lower fibres, which are directed more obliquely than the upper ones, end by being inserted, shortly tendinous, into the medial border of the patella for its upper half. A few superficial fibres also join the margin of the rectus tendon and from its lower border an expansion is given to the capsule of the knee-joint.

(d) The **crureus** (*vastus intermedius*) (fig. 80) has a fleshy origin from the anterior surface of the femur for its upper two-thirds, from the lateral surface of the bone in front of and below the attachment of the *vastus lateralis*, and from the distal half of the lateral intermuscular septum. The fibres are directed downwards, those of the lateral and distal part also considerably forwards, and they end on a superficial aponeurotic lamella, which covers the anterior face of the muscle and is continued into a thin and broad tendon constituting the deepest portion of the common tendon. A little above the patella this tendon is continuous along its lateral border with the aponeurosis of the *vastus lateralis*, and it is connected, but less intimately, along its medial border with that of the *vastus medialis*.

The muscle is almost completely covered by the *rectus* and *vasti* muscles, but it becomes superficial on the lateral aspect of the thigh, below and behind the posterior border of the *vastus lateralis*. It consists of four or five superimposed fleshy layers, the origins of which form a series of transverse arches with intervening bare spaces on the front of the femur. Between this portion of the muscle and the *vastus medialis*, as has already been mentioned, the greater part of the medial surface of the bone is free from muscular attachment.

(e) **M. Subcrureus**.—This name is given to one or two thin bands of fibres, which might be regarded as the deepest layer of the *crureus*. It arises from the distal part of the anterior surface of the femur, and is inserted below by scattered fibres into the upper part of the synovial membrane of the knee-joint.

The **common tendon** (fig. 80) of the quadriceps muscle consists of two parts, *suprapatellar* and *infrapatellar*, the patella being a large sesamoid bone developed in the tendon. The *suprapatellar tendon* consists of a superficial and a deep portion. The superficial portion is formed by the tendon of the *rectus femoris*. This, having received some superficial fibres from the aponeurosis of the two *vasti*, is attached to the ridge bordering the basal surface of the patella and is continued downwards over the anterior face of the bone into the superficial portion of the *infrapatellar tendon*. The deep portion consists of the tendon of the *crureus* united laterally with the aponeurosis of the *vastus lateralis* and medially with that of the *vastus medialis*. It is attached to the base of the patella, according to Poirier, as two lamellæ, one formed by the union behind the tendon of the *rectus* of the aponeuroses of the two *vasti*, and a second deeper formed by the tendon of the *crureus*. The lower fibres of both *vasti* are inserted by short tendinous fibres into the upper parts of the lateral and medial borders of the patella respectively, and expansions are given to the capsule of the knee-joint. The *infrapatellar tendon* springs from the apex and the lower border of the patella, and contracting somewhat, forms a very strong flat band which is attached below to the distal part of the tuberosity on the fore part of the head of the tibia. Beneath the *suprapatellar tendon* there is a large bursa which, in most cases, freely communicates with the cavity of the knee-joint; a bursa is also placed between the *infrapatellar tendon* and the proximal part of the eminence of the tibia, but has no connexion with the joint cavity. Bursæ are said to occur fairly frequently between the layers mentioned above into which the *suprapatellar tendon* may be resolved (Thiele, Poirier, etc.).

Relations.—The rectus is covered at its proximal part by the tensor fasciæ latae, iliacus, and sartorius muscles, and the acetabular tendon lies beneath the glutæus minimus. In the rest of its extent it is covered only by fascia. It rests upon the capsular ligament of the hip-joint and the deep parts of the quadriceps. Behind it also pass the lateral circumflex artery and branches of the femoral nerve. The vastus lateralis forms the large mass on the lateral aspect of the thigh. It is covered by the ilio-tibial band of the fascia lata, and the anterior border is concealed by the rectus. It rests on the crureus, and the branches of the lateral circumflex artery and femoral nerve entering it close to its anterior border pass between the two. The vastus medialis is covered partly by the sartorius and rectus; between these muscles it is superficial, giving rise to the prominence at the lower part of the medial aspect of the thigh. In the middle two-fourths of the thigh it forms the lateral wall of the space called *Hunter's canal*, which lodges the femoral vessels and is closed by a strong aponeurotic membrane sweeping under the sartorius from the vastus medialis to the adductor magnus. A portion of the crureus left uncovered by the vastus lateralis becomes superficial above the knee on the lateral aspect of the thigh.

Varieties.—The deep parts of the quadriceps are not liable to many anomalies. The vasti are sometimes bilaminar, a condition which is normal in some birds and certain rodents. This, in the case of the vastus lateralis, is the accentuation of a normal feature; the muscle can be partly resolved into two layers, between which vessels run, by incising a cellular interval along the anterior border. In lower mammals there may not be the same degree of separation of the three portions as in man; thus the vasti may be continuous with the crureus, and all three parts may be united into a common fleshy mass. The quadriceps of the thigh corresponds in a general way with the triceps group, including the anconæus in the arm. The separation into the different heads begins to show in the reptilia.

Nerves to the Anterior Group of Muscles.—All the muscles of the anterior group are supplied from the femoral nerve. The nerve for the *sartorius* arises high up and reaches the deep surface of the muscle in its proximal fifth. The nerve gives off a number of branches which form extramuscular loops over the upper half of the muscle before they enter it. The branches enter along a line from 23 to 24 cm. below the anterior superior iliac spine. Along the whole length of the muscle there is an intramuscular plexus with elongated loops corresponding to the long parallel muscular fasciculi. The *rectus femoris* is supplied by a single nerve. It divides into some five branches which enter the posterior aspect of the upper half of the muscular belly near the medial border. The branches sink into the muscle along a line extending from 8 to 20 cm. below the anterior superior spine. The first twig is recurrent and runs up on the proximal tendon. The lateral part of the muscle is supplied by the proximal, the medial by the distal twigs. The branch for the *vastus lateralis* reaches its muscle by passing between its anterior border and the crureus, and sinks into its deep surface about its middle. There are two main twigs; an upper which supplies about the upper half and yields branches ascending towards the origin, and a lower to the distal part of the muscle. The nerves to the *vastus medialis* and *crureus* enter their muscles on their superficial aspect and connecting loops are formed between them, while the nerve to the vastus lateralis is quite independent. The main nerve to the vastus medialis often comes off in common with the saphenous nerve and accompanies it to the mouth of Hunter's canal, where it enters the muscle. Some proximal twigs are given off above this. The crureus has two main twigs, a lateral to the proximal portion of the muscle and an anterior to the fore part. From the last a slender filament runs down along the medial border of the crureus, between it and the vastus medialis, to supply the *subcrureus*.

The Medial Group of Muscles

This group includes the pectineus, gracilis, adductor longus, brevis, and magnus, as well as the obturator externus. With the exception of the pectineus, the position of which is doubtful, and the ischial head of the adductor magnus which is developed with the posterior group of muscles, the muscles of the group arise from a common premuscle mass. This is first divided into two parts, representing the superficial and deep muscles, and these are again subdivided into the definitive muscles. The obturator is the main nerve of supply. The adductor mass in the thigh is remarkable for its powerful development as compared with the corresponding mass in the arm, which is represented by the coracobrachialis.

M. Pectineus (figs. 79, 80).—The pectineus muscle is the highest muscle of this group. It is flat and oblong, and arises by fleshy fibres from the ilio-

pectineal line and slightly from the surface of the bone in front of it, between the ilio-pectineal eminence and the pubic spine. A few superficial fibres spring also from the upper part of the fascia covering the muscle. Inclining outwards and backwards as it descends, it is inserted by a flat tendon into the femur behind the trochanter minor, and into the upper part of the line which runs from this to the linea aspera.

Relations.—By its anterior surface the pectineus is in relation with the pubic portion of the fascia lata and the femoral vessels; by its posterior surface with the obturator nerve, external obturator and adductor brevis and the capsule of the hip-joint. Its lateral border is in contact with the psoas magnus, and the median circumflex vessels pass between the two; its medial border touches the adductor longus.

Varieties.—The pectineus is not infrequently divided into two parts, which receive their nerves from different sources, viz. the medial from the obturator, the lateral from the femoral. This division occurs naturally in many lower mammals as well as in some lower primates. A common variation is union with the adductor longus, and this again is a normal feature in many mammals including some of the inferior primates. It is probable that in the pectineus we have the union of two elements derived one from the ilio-psoas, and the second from the adductor mass. Accessory fasciculi may unite the pectineus with the obturator externus, the iliacus, the capsule of the hip or the small trochanter.

M. Gracilis (figs. 79, 80, 84).—This muscle lies along the medial aspect of the thigh and is superficial throughout. Long, slender, and strap-shaped, it arises by a thin aponeurotic tendon from the pubic bone, along the symphyseal margin for its lower half and the whole length of the descending ramus. The fleshy belly, thin and flat at first, becomes narrower and thicker as it descends, and ends in the lower third of the thigh in a long rounded tendon. This tendon descending vertically behind the prominence of the lateral condyle turns forward below the knee and becoming thin and expanded is inserted into the medial surface of the tibia, on the same plane with, but higher than, the semitendinosus and under cover of the tendon of the sartorius. As it passes over the knee-joint the tendon crosses the medial collateral ligament, but is separated from it by a bursa.

Varieties.—Occasionally the gracilis gives some fibres to the fascia lata, and in rare cases to the fascia of the leg.

M. Adductor Longus (figs. 79, 80).—The long adductor is a flat triangular muscle placed in the same plane as the pectineus and medial to it. It arises from the body of the pubic bone below the crest and near the angle, by a short, stout tendon which spreads into an aponeurotic lamella along the anterior border of the muscle. The fleshy fibres springing from this are inserted into the medial lip of the linea aspera, through the medium of a broad aponeurotic tendon, which spreads on both surfaces of the muscle, and is intimately connected with the vastus medialis in front and adductor magnus behind.

Relations.—The inner border of the muscle is in apposition with the gracilis and forms the medial boundary of Scarpa's triangle. It stands out very prominently under the skin when the thigh is abducted. The lateral border is applied to and sometimes connected with the pectineus above, but is separated from it by a small interval below. The femoral vessels rest on its anterior surface. Medial to the vessels the muscle is covered by the fascia lata and lower down by the sartorius. The posterior surface rests on the adductor brevis and adductor magnus, the deep femoral artery and the superficial part of the obturator nerve intervening.

M. Adductor Brevis (fig. 80).—This muscle, concealed from view by the adductor longus and pectineus, arises by tendinous and fleshy fibres from the femoral surface of the body and descending ramus of the pubic bone, below the adductor longus and between the gracilis and obturator externus. Thick above

and broad below, the muscle is directed obliquely backwards and outwards, and is inserted by a flat tendon into the whole of the line leading from the trochanter minor to the linea aspera, immediately behind the pectineus. It is frequently found partially divided into an upper and lower portion separated by the perforating branch of the deep femoral artery which pierces it.

Relations.—The short adductor lies behind the adductor longus at its origin and the pectineus at its insertion. Its deep surface rests on the obturator externus above and adductor magnus below. The two divisions of the obturator nerve lie, the one in front the other behind the muscle. The deep femoral artery is placed in front of it and the medial circumflex artery passes between it and the obturator externus.

M. Adductor Magnus (figs. 78, 80).—The great adductor is a large triangular sheet of muscle, placed posterior to the preceding muscles. It arises from the pubic arch and ischial tuberosity and is inserted (1) into the back of the femur along the medial lip of the gluteal line, the linea aspera, and the upper part of the supracondylar line, and (2) by a distinct rounded tendon into the adductor tubercle on the medial condyle of the femur. When the development of the muscle is examined we find that it consists of two originally independent parts, the obturator and the ischio-condylar. These merge in man, but in the lower primates the ischio-condylar factor persists as a separate muscle. But the obturator portion is again subdivided into a superior and anterior portion—which is as a rule quite distinct and is often described under the name of the *adductor minimus*—and a posterior and inferior portion. With this last the ischio-condylar part is conjoined at its origin, but is separately inserted by the rounded tendon just mentioned on the adductor tubercle.

The upper and anterior portion or adductor minimus arises slightly from the body of the pubic bone, medial to the adductor brevis, and from the margin of the ischio-pubic rami between the gracilis and the obturator externus. From this origin the muscular fasciculi diverge to form a thin triangular sheet which is attached by short tendinous fibres to the back of the femur along the medial lip of the gluteal line from the lower border of the quadratus femoris to the linea aspera, and as a rule along that line for about a quarter of its length. The remainder of the muscle takes origin from the posterior part of the ischial ramus internal to the foregoing by short tendinous fibres, and from the lower part of the ischial tuberosity by a strong tendon which descends on the posterior border of the muscle for the upper third of the length of the thigh. The muscular fasciculi springing from the fore part of this origin, and the lateral side of the tendon, pass obliquely to the linea aspera, where they are attached below and in sequence with those of the upper portion of the muscle, and also to the supracondylar ridge for about an inch of its length. The fasciculi from the deep aspect and medial border of the tendon, which represent the ischio-condylar part of the muscle, descend vertically to end, in the distal third of the thigh, on the tendon attached to the adductor tubercle. Looking at the muscle as a whole it will be noticed that the muscular fasciculi coming from the body of the pubic bone are short and horizontal in direction, while the succeeding ones, becoming longer, are directed with increasing degrees of obliquity downwards until those from the ischial tuberosity descend almost vertically.

The muscular sheet is attached to the femur by a narrow aponeurotic border which is interrupted at intervals to form a series of three or four fibrous arches through which the perforating arteries pass. The tendon is also attached by an aponeurotic layer to the medial supracondylar ridge, and between this part of the insertion and the other there is an interval left for the passage of the femoral

vessels backwards into the popliteal space. Extending upwards from the opening for the femoral vessels on the anterior face of the muscle is an aponeurotic membrane, which consists of transverse fibres passing from the surface of the vastus medialis to the adductor magnus and adductor longus muscles. It becomes thinner as it ascends and encloses a three-sided passage called *Hunter's canal* which contains the femoral artery and vein together with the saphenous nerve.

Relations. The adductor magnus is in contact in front with the long and short adductors and vastus medialis, medially with the gracilis and sartorius, behind with the gluteus maximus and hamstrings, and above with the obturator externus and quadratus femoris. The great sciatic nerve descends on its posterior aspect; the deep branch of the obturator and the profunda artery are related to it in front, while along its line of attachment to the femur it is pierced by the perforating arteries and the femoral trunk. A bursa is said to be present between the upper part of the adductor magnus and the trochanter minor as it passes over this to its insertion.

Varieties.—The degree to which the adductor mass is divided up into individual muscles varies in lower forms. In the human subject all three muscles may be subdivided into a greater number of portions than is normal. Thus the adductor longus may be double; the adductor brevis is frequently found divided into two or three parts; and it has been already shown how the adductor magnus is really a complex mass. The adductor minimus can almost always be identified, while the ischio-condylar part is sometimes found distinct from the rest of the muscle, as it normally is in apes. The nerve supply of the ischio-condylar portion from the great sciatic nerve shows that it really belongs to the flexor group, was in fact a part of the hamstring muscles. It has been detached from this group and joined to the adductors. Fusions may on the other hand occur, thus the adductor magnus may be fused with the quadratus femoris, or with the long or the short adductor. The adductor longus has been seen to extend as far as the knee with its tendon of insertion inseparable from that of the adductor magnus.

M. Obturator Externus (fig. 80).—This very deeply placed muscle arises from the outer face of the obturator membrane for the medial half of its extent, from the femoral surface of the pubic bone below the spine, and from the conjoined pubic and ischial rami. The fasciculi converge, as they are directed laterally in the groove between the acetabulum and the ischial tuberosity, to the lower part of the hip-joint; then winding backwards and upwards, in close contact with the lower and hinder surfaces of the neck of the femur, they end in a tendon which is inserted into the bottom of the digital fossa of the great trochanter.

Relations.—The external obturator is concealed in front by the pectineus, ilio-psoas, adductor brevis and adductor magnus. Near its insertion it is covered posteriorly by the quadratus femoris. Its deep surface is closely related to the capsule of the hip-joint as it passes backwards, and here between the tendon, the capsule, and the neck of the femur there is sometimes a bursal sac.

Varieties.—The muscle shows little variation. Sometimes a part of the muscle is isolated above the point of exit of the obturator nerve. The muscle may be divided into three slips, and this is described sometimes as the normal arrangement. It may be connected with the adductor brevis.

Nerve Supply of the Medial Group of Muscles.—The *pectineus* is supplied by a twig from the femoral nerve which reaches the muscle by passing under the vessels. It may also receive a twig from the obturator or accessory obturator nerve when present. The *ischio-condylar part of the adductor magnus* receives its supply from the great sciatic nerve by a branch which is distributed to its posterior surface and generally comes off with the nerve to the semimembranosus. According to Froshe and Fränkel this nerve is also distributed to the lower fibres of the muscle attached to the linea aspera. The *remainder of the adductor magnus*, the *two other adductors*, the *gracilis* and *obturator externus* all receive their nerves of supply from the obturator. The gracilis, adductor longus, and adductor brevis are supplied from the anterior branch of the nerve, the adductor magnus from the posterior or deep division, while a third deep twig which arises from the nerve in the canal goes to the obturator externus. The nerve to the gracilis reaches the muscle in the proximal third of the thigh by several branches which enter along a line from a point 8 cm. to another 16 cm. from the symphysis.

Action of the Muscles on the Knee-Joint.—In any consideration of the action of the muscles which produce movement at the knee-joint, the relation of the line of the body weight to the axis of the joint (when that weight is being transmitted through the lower limbs) must always be borne in mind. For, in those positions in which it passes in front of the axis it acts as an extensor force,

but if it lie behind the axis it tends to produce flexion. It constitutes, therefore, in many positions of the joint an antagonistic force to one or other of the two muscle groups which are related to the joint. The movements within the knee-joint are, of course, extremely complicated, but so far as the gross displacements of its components are concerned, they may be described as the bending movements of flexion and extension and, though very secondary, the rotatory movements of pronation and supination.

In regard to the *work value* of the flexor and extensor muscles, the latter are the more powerful group (in the proportion of 42:45 (Fick), an excess which is a feature peculiarly human and correlated with the requirements of the upright posture). The confinement of the attachment of the flexors to the upper ends of the tibia and fibula is also a human characteristic, and contrasts strongly, but as a morphological rather than as a mechanical fact, with the wide insertions in the quadrupeds.

Of all the muscles which act as flexors at the knee, only two—the short head of the biceps and the popliteus—are confined in their action to this joint. Of the others some act also as extensors at the hip-joint, namely the long head of the biceps, the semimembranosus and semitendinosus; some, the sartorius and the gracilis, act as flexors at the hip; and some, the gastrocnemius and plantaris, act at the ankle-joint. Those muscles which also act on the hip-joint have in common the property that the moment of their contraction increases as the flexion advances to 90°, but decreases rapidly in further flexion. Thus in full flexion of the knee these muscles have no further possibility of contraction and can effect no movements at the hip. Conversely, having produced full extension of the hip, the hamstring group cannot effect full flexion of the knee, since their possibility of shortening is already considerably exhausted in the former movement: they are *actively insufficient*. In passing towards extreme flexion of the hip the hamstring muscles are so stretched that if the knee remain extended they act as a limiting mechanism of the hip movement. If extension is not actively maintained at the knee, flexion at that joint will follow flexion of the hip, in consequence of the ligamentous action of these muscles: they are then *passively insufficient*. Those muscles which are pure flexors of the hip can, therefore, effect flexion of the knee as the result of the hamstring group functioning as ligaments. The popliteus muscle is commonly considered to be a weak flexor of the knee-joint, but as pointed out by Winslow the proximity of its attachment to the axis of motion and the obliquity of its fibres render it ill contrived for such a function: indeed it is classed as an extensor muscle by Furst. It has been explained by Fick, however, that its action will depend on the relation of its femoral attachment to the axis of motion of the joint. This varies in an antero-posterior direction in different positions of the joint: so that in extreme extension the muscle is an extensor in action, since the axis of motion of the joint is carried forward in the change from the position of flexion.

The extensor muscle of the knee is the quadriceps extensor cruris mass, the rectus femoris component of which passes over the hip-joint, of which it is a flexor. The vasti are extensors of the knee-joint and elevators of the patella. By the intervention of the patella in their insertion their virtual lever and, therefore, their moments of contraction are substantially increased. This consideration is of special significance in the thrust of the extended leg from the ground in walking. The patellar fibres of the vastus medialis draw the patella inwards as well as upwards during extension of the knee. The action of the tensor fasciæ latæ as an extensor at the knee is insignificant. The subcrureus muscle through its attachment to the suprapatellar synovial membrane draws upwards that reduplication during extension, and prevents it being caught between the femur and the advancing patella.

The voluntary rotatory movements of the knee, as distinct from those accompaniments in the movements of flexion and extension, can take place only in positions of flexion. With the exception of the tensor fasciæ latæ, therefore, the muscles which effect these rotatory movements are the flexor muscles. The biceps and the tensor fasciæ latæ—the latter but to slight extent—are the lateral rotators of the leg, and the medial rotators, in the order of their moments of contraction, are the semimembranosus, semitendinosus, sartorius, popliteus, and gracilis. Through its attachment to the capsular ligament, the popliteus serves to prevent the posterior part of the capsule being pulled forwards between the femur and tibia during flexion.

THE MUSCLES AND FASCIÆ OF THE LEG

Fasciæ.—The deep fascia of the leg invests the muscles closely, but is not continued over the subcutaneous surfaces of the bones. It is intimately blended with the periosteum over the head and the anterior and medial borders of the tibia, the head of the fibula, and the tibial and fibular malleoli. Posteriorly over the popliteal space it is directly continuous with the fascia lata over the back of the

thigh, and on each side of the knee it receives accessions from the tendons of the biceps laterally, and the sartorius, gracilis, and semitendinosus medially. From the deep surface of the fascia on the lateral aspect of the leg two intermuscular septa are sent inwards, to be attached to the anterior and lateral borders of the fibula respectively. Thus, as the fascia is attached firmly to the anterior and medial borders of the tibia, three compartments are defined, an anterior which lodges the tibialis anterior and the extensors of the toes, a lateral which encloses the peroneal muscles, and a posterior, very much larger, which contains the superficial and deep layers of the muscles of the calf, the two layers being separated by a horizontal septum presently to be described.

The *fascia over the anterior surface of the leg* is thicker than on the posterior aspect, especially in the proximal part, where it is very dense and gives origin to the subjacent muscles. It sends an intermuscular septum inwards between the tibialis anterior and extensor digitorum longus. Somewhat thinner over the distal part of the leg, the fascia is again much thickened just above the ankle, where it forms a broad band which stretches transversely across from the anterior border of the tibia to the anterior border of the fibula, and binds down the extensor tendons descending to the foot. This band is commonly named the *ligamentum transversum* (figs. 81, 82), or the upper part of the anterior annular ligament of the ankle. On the *lateral aspect of the leg* the fascia is fairly dense proximally, but is thinner distally. Behind the lateral malleolus it is continuous with the band of fibres known as the *lateral annular ligament*.

On the *posterior aspect* of the knee, over the popliteal space the fascia consists of strong transverse fibres which bind together the muscles on either side; it is perforated by the small saphenous vein at the lower part of the space. Beneath this the fascia is loose, and in thin subjects a deep lamella extending between the heads of the gastrocnemius may be defined. Over the gastrocnemius lower down it becomes much thinner, but is denser again at the ankle when it passes from the sides of the tendo Achillis to the malleoli. The superficial layer of muscles is separated from the deep layer by a fascial septum which extends over the deep muscles, from the medial border of the tibia to the lateral border of the fibula, and binds them down to these bones. This septum is thin and weak where it is covered by the gastrocnemius and soleus, but becomes a strong lamella below when it escapes from under these muscles and approaches the malleoli. Behind the medial malleolus the superficial and deep layers together merge in the band known as the *medial annular ligament*. The transverse fascial septum is limited proximally by the attachment of the soleus to the fibula and soleal line on the tibia, but above this a strong fascial layer covers the surface of the popliteus muscle. It is to a considerable extent formed by an accession of fibres from the tendon of the semimembranosus.

Anterior Annular Ligament (figs. 81, 82).—This structure is commonly and conveniently described as consisting of two portions, one placed at the lower end of the leg, the second, for which in strictness the name should be reserved, opposite the bend of the ankle.

The *upper band* (*ligamentum transversum*) has already been described with the deep fascia. The synovial sheath of the tendon of the tibialis anterior alone rises high enough to lie under this part of the ligament.

The *lower band* presents superficially the appearance of the letter Y, placed thus < upon its side, being single in its lateral half and divided into two limbs medially. The stem of the Y-shaped band springs from the hollow of the calcaneus extending back to the lateral end of the interosseous talo-calcaneal ligament and the posterior articular surface of the talus. The anterior or superficial fibres,

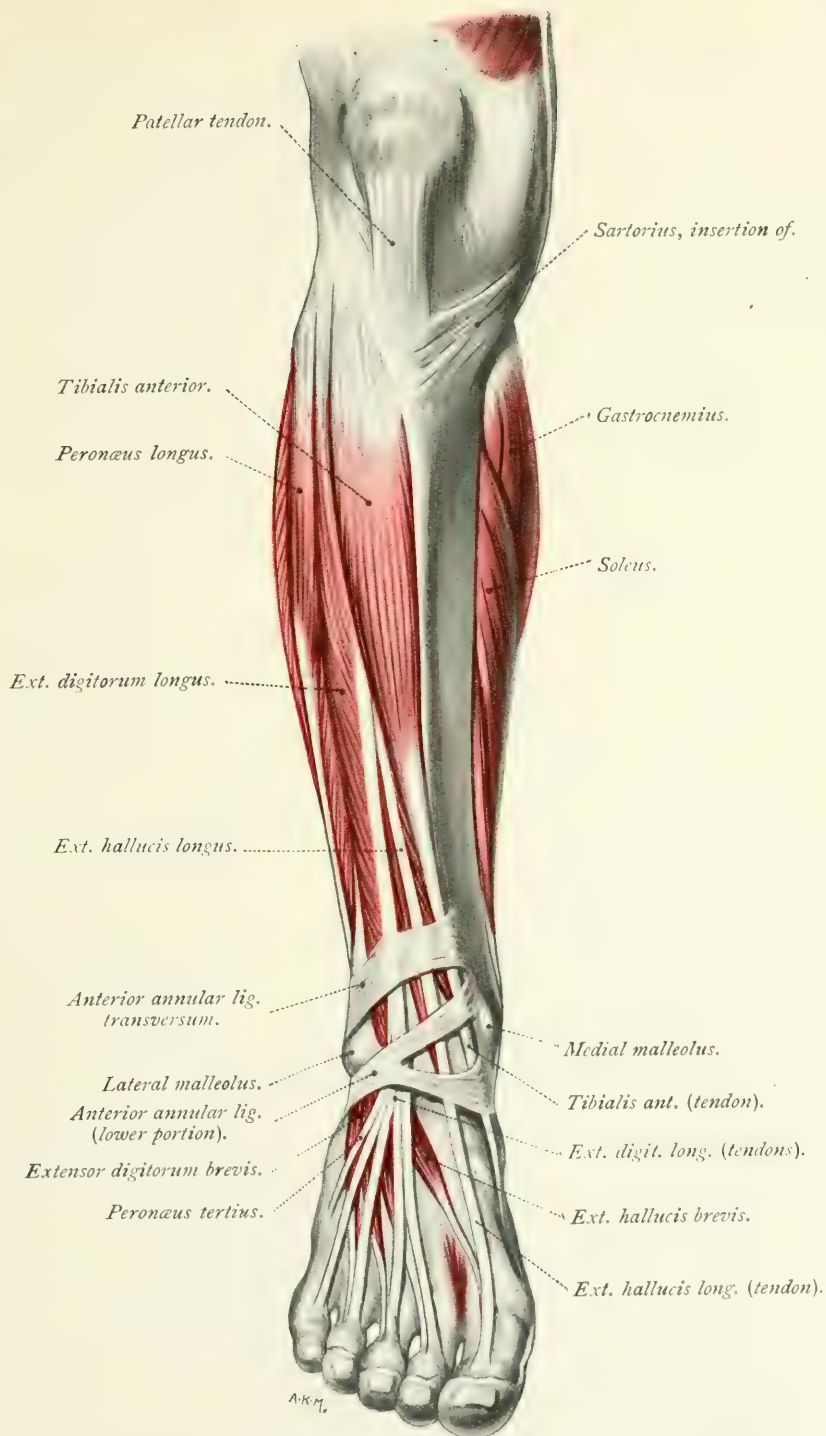


FIG. 81.—MUSCLES ON EXTENSOR ASPECT OF LEG.

attached to the fore part of the hollow, pass medially over the tendons of the peroneus tertius and extensor digitorum longus, and are continued into the limbs of the ligament. The upper limb, crossing the tendon of the extensor hallucis proprius, divides to enclose the tendon of the tibialis anterior. Relatively few of the fibres pass superficial to the tendon, and it is therefore less firmly held down than the other tendons. The lower limb, less well marked, passes over both tendons and ends on the medial aspect of the foot by merging with the fascia of the sole.¹ A strong strand of deep fibres leaves the deep surface of the ligament on the medial side of the tendon of the extensor digitorum, and turning round this returns to be attached to the back part of the hollow, where it is connected by fibres with the interosseous talo-calcaneal ligament. In this way the tendons of the peroneus tertius and extensor digitorum are bound down to the talo-calcaneal hollow by a pulley-like loop (the *fundiform ligament* of Retzius). By this arrangement the pull on the tendons to the toes is kept in the axis of the foot. A similar but weaker loop surrounds the tendon of the extensor hallucis. There are thus three compartments under the ligament each with its synovial sheath. In many cases there is also a bursa between the fundiform ligament and the outer side of the neck of the talus.

Medial Annular Ligament (fig. 84). This ligamentous band crosses the hollow between the medial malleolus and the heel through which the tendons of the flexor muscles run. Its proximal border, continuous with the fascia of the leg (more especially the intermuscular layer), is very imperfectly defined. Its distal margin is but little more distinct, being continuous more or less with the tendinous origin of the abductor hallucis which arises from it. Its anterior extremity is attached to the malleolus, and its posterior to the medial side of the calcaneus, but between these two points it reaches over several osseous grooves so as to form canals for the passage of tendons. The first canal (next the malleolus) contains the tendon of the tibialis posterior; the second that of the flexor digitorum longus, each being provided with a synovial lining; then follows a wider space for the passage of the posterior tibial vessels and nerve; lastly, a fourth canal transmits the tendon of the flexor hallucis longus, but it is provided with a special and independent fibrous sheath, which bridges over the groove on the back of the talus, and is continued forward under the sustentaculum tali. It is lined with a separate synovial bursa.

Lateral Annular Ligament. This name is here given to a band of fibres extending from the point of the fibular malleolus and the margin of the groove on its posterior aspect to the lateral surface of the calcaneus. It keeps in place the tendons of the long and short peroneal muscles, and consists of two stronger portions separated by a thinner part. The proximal part, named in the B.N.A. the *superior peroneal retinaculum*, binds the tendons to the back of the malleolus, the distal part, the *inferior peroneal retinaculum*, attaches them to the outer face of the calcaneus. The fibrous sheath of the tendons is common above, but is divided into two compartments below by a septum which is attached to the calcaneal tubercle. The synovial sheath invests both tendons, but divides into two processes where they separate from one another. Subcutaneous bursæ are sometimes developed over the malleoli, especially the lateral, and more rarely over the lower end of the tendo Achillis.

¹ Occasionally some fibres pass lateralwards from the point where the limbs of the Y diverge to the lateral malleolus, giving the ligament a cruciform arrangement, hence the B.N.A. name *lig. cruciatum*.

The Muscles of the Anterior Region of the Leg and Dorsum of the Foot

The group of leg muscles now to be described includes five muscles, the tibialis anterior, extensor hallucis longus, extensor digitorum longus, peroneus tertius, and extensor digitorum brevis. From the developmental standpoint the peroneal muscles should be included in this group as they are developed from the same common premuscle mass. The extensor digitorum brevis is at first connected mainly with the peroneal muscle mass, and strictly, from the morphological point of view, should be described along with the peroneal muscles. It is, however, supplied by the same nerve trunk as the anterior tibial group of muscles, and is therefore included in one group with them. As will be explained later the nerve supply is, in this case, not a certain guide to the morphology of the muscle. The extensor mass is differently divided up from that of the forearm. The tibial marginal mass is reduced, and owing to the fixity of the bones the supinator element is lacking. Further, owing to the change in position of the great toe, and the fixity of its tarso-metatarsal joint, certain muscles of the thumb are not differentiated. The extensor brevis digitorum, on the other hand, is more complete but displaced on to the dorsum of the foot.

M. Tibialis Anterior (figs. 81, 82, 84).—The anterior tibial muscle arises from the lower margin of the lateral condyle of the tibia, from the lateral aspect of the bone in its proximal half, from the adjoining portion of the interosseous membrane, from the strong fascia covering it and the intermuscular septum between it and the long extensor of the toes. The muscular fasciculi end upon a strong flat tendon which appears along the anterior border of the muscle in the middle of the leg and receives fleshy fibres on its posterior aspect down nearly to the anterior annular ligament. Passing beneath the ligament the tendon inclines medianwards, and turning on itself divides into two slips, deep and superficial. The former is inserted into an oval mark on the lower part of the medial surface of the first cuneiform bone and the latter into the contiguous extremity of the first metatarsal bone. Between the two slips is a small bursa generally continuous with the synovial cavity of the cuneo-metatarsal joint, while under the deep slip there is a second smaller sac.

Relations.—The muscle lies throughout under the crural fascia. It rests on the tibia and interosseous membrane. Its lateral surface is in contact with the extensor digitorum longus and extensor hallucis longus, the anterior tibial vessels and nerve intervening. The tendon passes over the distal end of the tibia, ankle-joint, and medial side of the tarsus.

Varieties.—The tendon is frequently found divided into a cuneal and metatarsal slip for a certain distance upward, and in very rare instances the division may involve the whole muscle. In a few cases a deep portion has been found inserted into the talus, and the tendon has also been seen giving a slip to the head of the first metatarsal or the base of the first phalanx. These various degrees of division of the muscle represent conditions which normally occur among the lower primates, in which there is an *abductor longus hallucis* more or less independent. A separate muscular slip, bearing the name *tibio-fascialis anticus*, sometimes occurs. It arises from the lower end of the tibia and ends on the annular ligament or deep fascia, and may be represented by a tendinous slip from the tibialis anterior.

M. Extensor Hallucis Longus (figs. 81, 82).—Placed between the tibialis anterior and extensor digitorum longus, the long extensor of the great toe arises by a narrow origin from the middle two-fourths of the antero-medial surface of the fibula and the adjoining part of the interosseous membrane. The muscular fasciculi are short and oblique and end upon a tendon placed along the anterior border of the muscle. Reaching the ankle, and having passed through a distinct

compartment in the anterior annular ligament, the tendon passes over the dorsum of the foot, to be inserted into the base of the terminal phalanx of the great toe. An expansion, given off from the tendon on each side, but stronger on the lateral side, spreads over the metatarso-phalangeal articulation; and in the majority of cases there is a slip from the medial edge of the tendon inserted into the base of the first phalanx.

Relations.—The muscle is partly concealed by the muscles between which it is placed. It lies lateral to the anterior tibial artery at its origin, but crosses in front of the vessel in the distal third of the leg, and is medial to it on the foot.

Varieties.—The extensor hallucis longus is occasionally united at its origin with the extensor digitorum longus. The tendon may be divided into three slips confined to the great toe, and a slip to the second toe has been observed.

M. Extensor Digitorum Longus (figs. 81, 82).—Situated between the tibialis anterior and extensor hallucis longus and the peroneal muscles, the common extensor of the toes arises from the lateral condyle of the tibia and from the antero-medial surface of the fibula, anterior to the extensor hallucis longus, for about two-thirds of its length. It also springs from the upper part of the interosseous membrane, from the fascia covering it, and from septa between it and the adjoining muscles, but more especially from that attached to the anterior border of the fibula between it and the peroneal muscles. Most of the muscular fibres come from this strong aponeurotic septum rather than from the bone direct. The tendon appears along the anterior border of the muscle, and the muscular fasciculi, pennately arranged, join its posterior border. It divides into four tendons, which, along with the tendon of the peronæus tertius, pass through the fundiform loop of the anterior annular ligament, and then diverging on the dorsum of the foot pass to the four outer toes. The three medial tendons are each joined at the outer side, on the first phalanx, by a tendon of the short extensor. All the four tendons are continued into expansions which are attached to the first phalanx and are joined on the first phalanx by tendinous slips from the lumbricals and interosseous muscles. These expansions have not the regular character seen in the corresponding expansions in the hand, but are generally developed only on one or other side of the tendon as the case may be. Each tendon divides into three slips, the middle being inserted into the second phalanx, while the lateral unite and are inserted on the third, in a manner exactly similar to the arrangement of the extensor tendons of the fingers (p. 142).

M. Peronæus Tertius (figs. 81, 82).—The origin of the peronæus tertius is simply the extension downwards to the lower third or more of the fibula of the origin of the extensor digitorum longus. Its tendon is inserted into the dorsal surface of the base of the fifth metatarsal, but quite as commonly it ends partly or wholly upon the fourth metatarsal.

Varieties.—The varieties of the extensor digitorum longus concern mainly the mode of origin and arrangement of its various tendons. They may be found doubled, or extra slips may be given off from one or more tendons to their corresponding metatarsal bones, or to the short extensor, or to one of the interosseous muscles. A slip to the great toe from the innermost tendon has also been seen. As compared with the corresponding tendons in the hand it is to be observed that all are independent from their neighbours. There are no connecting bands between them. Further, the slip to the fifth toe is not reduced like that of the little finger owing to the absence of the digital insertion of the extensor minimi digiti proprius. The peronæus tertius varies much in size. Sometimes it may be as large as the extensor digitorum longus, or it may be absent. It is a muscle peculiar to man, and represents the extensor minimi digiti proprius of the arm with its insertion displaced to the base of the fifth metatarsal for the support of the outer side of the foot in walking. It is not so completely separated from the common extensor at its origin as the corresponding muscle of the arm. A slip occasionally given off to join the extensor tendon of

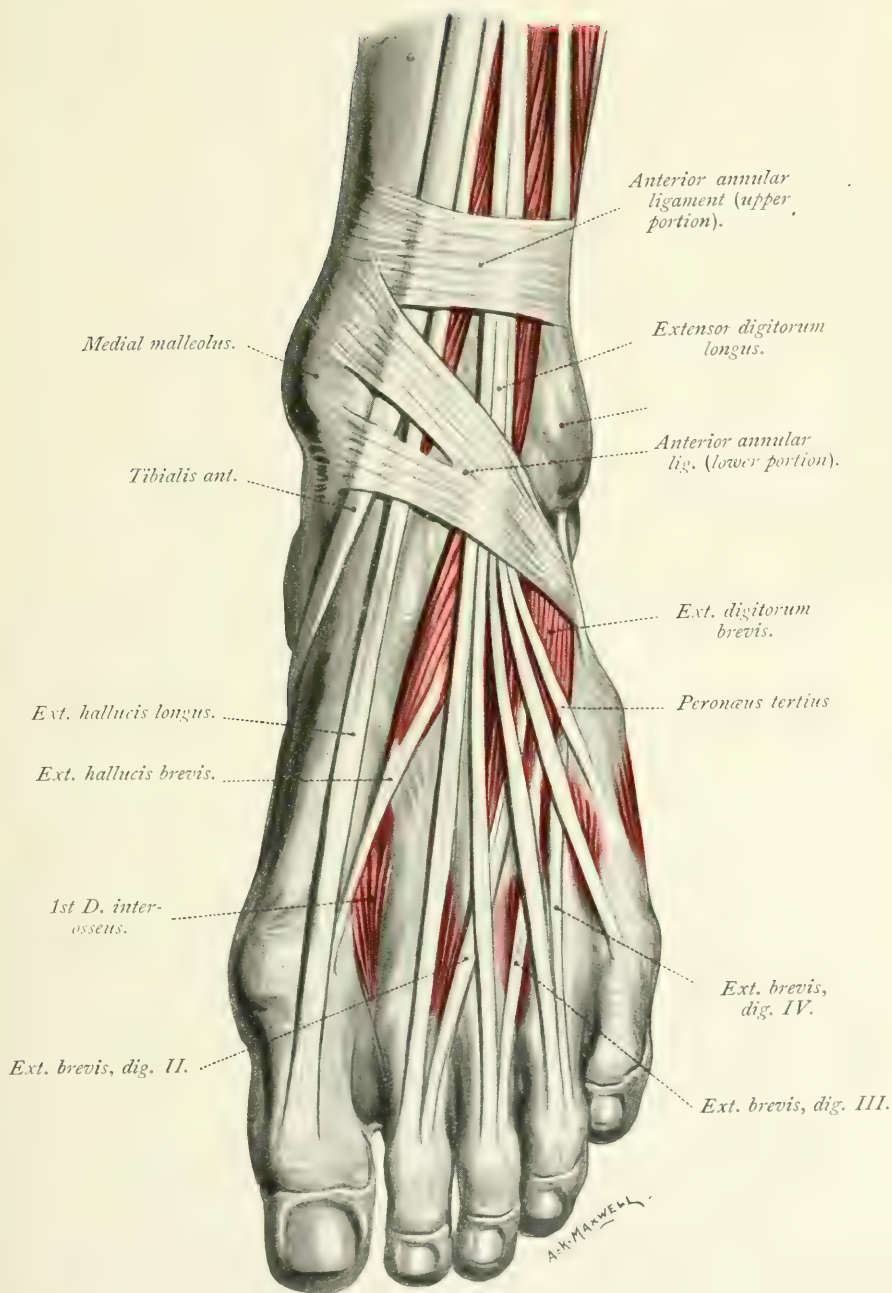


FIG. 82.—MUSCLES AND TENDONS ON THE DORSUM OF THE FOOT.

the little toe represents the radial tendon of the extensor minimi digiti proprius while the main tendon represents the ulnar slip in the hand.

M. Extensor Digitorum Brevis (fig. 82).—The short extensor muscle is placed on the dorsum of the foot. It consists of two parts, one going to the great toe, and therefore an **extensor hallucis brevis**, and the second distributed to the second, third, and fourth toes, the **extensor digitorum brevis**. The two parts are so closely conjoined at their origin that it is convenient to describe them together. The muscle arises from the fore part of the upper surface of the calcaneus, and the lower band of the anterior annular ligament and also from the lateral aspect of the bone in front of the groove for the peronæus brevis. The muscle mass is placed somewhat athwart the dorsum of the foot under the peronæus tertius and long extensor tendons, and divides into four small bellies in each of which the fibres are arranged pennately on a separate tendon. The first or innermost of these, crossing beneath the tendon of the long extensor of the great toe, and over the dorsal artery and nerve of the foot, reaches the base of the first phalanx of the great toe into the dorsal aspect of which it is inserted separately. The other three tendons become severally united to the fibular borders of the tendons of the long extensor tendons proceeding to the second, third, and fourth toes.

Varieties.—The short extensor of the toes is both ontogenetically and phylogenetically a fibular muscle. Its position on the dorsum of the foot is secondary. Something further will be said on this point under the head of the peroneal muscles. Meantime only some of the variations of minor interest will be briefly noted. An accessory fasciculus of origin from the talus and navicular bone or from the third cuneiform and third metatarsal bones has been observed passing to the second slip of the muscle, and one from the cuboid to the third slip. The tendons vary in number. They may be reduced to two or even to one, and cases have been described in which the muscle failed altogether. On the other hand, a slip in very rare instances may join the long extensor tendon of the little toe so that the slips are increased to five. This is a very rare arrangement. When five tendons are present it is usually due to the presence of supernumerary fascicles arising between the normal slips, and ending in various ways. Such slips are not infrequent, especially in the interval between the bellies of the great toe and the second toe. There is occasionally a single or double bursa between the short extensor muscle and the bases of the second and third metatarsal bones.

Nerves to the Anterior Crural Muscles.—All the muscles of the group just described are supplied by the anterior tibial (deep peroneal) nerve. The *tibialis anterior* receives three main nerves, or groups of nerves. The upper two come off while the nerve is still on the neck of the fibula, pierce the extensor digitorum longus and cross the interosseous membrane to sink into the muscle. The recurrent articular twig to the knee-joint comes off with the highest branch. This supplies the proximal third of the muscle roughly. The second branch gives several twigs into the muscular fibres arising from the upper part of the tibia and interosseous membrane. The third and largest branch comes off from the main trunk lower down and supplies the lower part, roughly the lower third, of the muscle. The highest branch enters the muscle from 4 to 5 cm. below the styloid process of the fibula, the middle series of twigs from 6 to 9 cm., the lowest series from 12 to 15 cm., below the same point (Capell). The *extensor digitorum longus* and *peronæus tertius* are supplied as follows. The upper part of the extensor receives two nerves which come off high up soon after the nerve has passed under the muscle into the interval between it and the anterior tibial muscle. The main nerve of supply, however, is a long descending branch which comes off a little lower down, runs the whole length of the muscle, supplies all its distal part, and ends by sinking into the peronæus tertius. The extramuscular branching corresponds to a line drawn from 6 cm. to 18 cm. below the head of the fibula (Froshe and Fränkel); 7.5 to 23 cm. from the styloid process of the fibula (Capell). The twig for the peronæus tertius enters its muscle at a point 25 or 26 cm. distant from the styloid process of the fibula. The *extensor pollicis longus* receives two, or it may be three nerves. The first of the three rises high up from the lateral side of the main trunk and sinks into the superficial face of the muscle near its origin; the second and the main nerve of supply enters its deep face; the third nerve enters the lowest part of the muscle. The larger second branch innervates four-fifths of the muscular belly (Froshe and Fränkel). Both these branches enter the muscle about the middle of the leg (mid-point between styloid process of fibula and lateral malleolus), the deep branch a couple of centimetres lower than the superficial. The nerve for the *extensor brevis digitorum* leaves the anterior tibial as it lies on the

capsule of the ankle-joint. It gives off a branch to the extensor pollicis brevis and turning lateral-wards ends in branches for the bellies of the second, third, and fourth digits. The extensor quartus digiti has been seen to receive a branch from the muscular portion of the musculo-cutaneous (superficial peroneal) nerve which passes to it from behind the lateral malleolus under the peroneal tendons (Bryce).

The Peroneal Group of Muscles

Under this head are described the muscles lying in the lateral crural compartment and supplied by the musculo-cutaneous (superficial peroneal nerve), viz. the peronæus longus and the peronæus brevis.

M. Peronæus Longus (figs. 81, 83, 90, 91).—The peronæus longus arises by a few fibres from the lateral tibial condyle, from the head and upper two-thirds of the lateral surface of the fibula, from the fascia of the leg, and from the inter-muscular septa between it and the extensor digitorum longus in front and the soleus and flexor hallucis longus behind. Its attachment to the bone is interrupted for about an inch below the head of the fibula where the lateral popliteal (peroneal) nerve passes beneath it. As the nerve lies under the muscle the musculo-cutaneous (superficial peroneal) nerve is given off and descending in its substance divides it into two portions sometimes described as separate heads. The muscular fasciculi end upon the posterior aspect of a flattened tendon which appears on the surface in the distal half of the leg. This tendon becoming free of fleshy fibres about 5 or 6 cm. above the ankle, and following the lateral surface of the bone, descends with the tendon of the peronæus brevis in the groove on the back of the lateral malleolus. It then inclines forward over the lateral side of the calcaneus to reach the lateral border of the cuboid; here again changing its direction it enters the groove on the under side of that bone, and is conducted in it across the sole of the foot to be inserted into an impression on the outer side of the tuberosity of the first metatarsal bone, and slightly into the adjoining part of the first cuneiform bone. A sesamoid fibro-cartilage, or sometimes a bone, is found in the tendon where it plays over the tuberosity of the cuboid. A single synovial sac invests both tendons above, but this is divided below when the tendons separate from one another. In the sole of the foot the tendon lies in a canal formed by an expansion of the calcaneo-cuboid ligament stretching over the groove on the cuboid to the bases of the metatarsal bones, and in this canal there is a second synovial sheath.

An offset is frequently given off from the tendon to the base of the second metatarsal bone. According to Le Double and Picou this is only an apparent attachment; the slip passes with the first dorsal interosseous muscle to be attached to the dorsal and lateral border of the first metatarsal below its head. A fibrous expansion is given off from the tendon as it enters the cuboid groove to the base of the fifth metatarsal and the attachment of the flexor brevis minimi digiti. The tendon is sometimes connected with the tendon of the tibialis posterior under which it crosses in the axis of the foot, and a slip from it to the third, fourth, or fifth metatarsal bone, or adductor obliquus hallucis, is occasionally seen. Sesamoid thickenings may be developed where the tendon lies behind the malleolus, or under the peroneal tubercle.

M. Peronæus Brevis (figs. 83, 85).—Placed deep to the preceding muscle the short peroneal muscle arises from the lower two-thirds of the lateral surface of the fibula, overlapping the peronæus longus in front, and from the intermuscular septa on each side of the peroneal fascial compartment. The muscular fasciculi end bipennately on a flattened tendon, which appearing on the lateral face of the muscle winds round the back of the fibular malleolus, and then inclines forward to be inserted into the tuberosity of the fifth metatarsal bone. In the majority of cases, a small slip leaves the tendon to join the long extensor tendon to the little

toe, or to be attached to the fore part of the metatarsal bone, or first phalanx of the little toe.

Varieties.—The peroneal muscles represent the fibular marginal muscle developed from the extensor mass. In some mammals and lower tetrapodal vertebrates the peronæus longus has a femoral origin. In rare cases in man fasciculi have been seen arising from the lateral femoral condyle, and it has been suggested that the fibular collateral ligament represents a primitive femoral attachment of the muscle. The name *peronæus accessorius* is the name given to a slip which arises high up on the fibula between the long and short peroneal muscles and joins the tendon of the longus in the sole of the foot. Another detached slip arising from the proximal part of the fibula and attached below to the fibular malleolus, the peroneal process of the calcaneus, or lateral ligament of the ankle, is probably to be considered as a separated portion of the peronæus longus, but it may represent a *peronæus digiti V superior, or longus*, such as seen in Catarrhine monkeys (Frets). There are other slips which arise from the lower part of the fibula behind the peronæus brevis and are attached to the lateral aspect of the calcaneus or the cuboid. These are vestiges of a muscle which appears in complete form in very rare cases, viz. the *extensor digiti quinti brevis*. Ontogenetically the extensor brevis digitorum is directly continuous with the peroneal group. In monotremes the whole extensor brevis arises from the fibula, and every phase between this primitive arrangement and that seen in man occurs in lower mammals, the slips descending, as it were, one by one on to the dorsum of the foot. The fibular slips are always supplied by a special branch of the musculo-cutaneous nerve, but the anterior tibial (deep peroneal) takes over the supply when they come to be limited to the dorsum of the foot. The penultimate stage is seen in carnivores and some lower primates when only one peroneal slip is left going to the fifth digit. In man this reappears in one or other of the forms mentioned. The theory formulated by Ruge that the short extensor has descended to the foot in phylogeny provides the only plausible explanation of the facts, and is strongly supported by observations of the present writer who found the special branch from the musculo-cutaneous nerve in a number of cases ending in the slip to the fourth toe of the normal extensor digitorum brevis.

Nerves to Peroneal Muscles.—The musculo-cutaneous (superficial peroneal) nerve gives off two branches to the upper part of the peronæus longus which arise from it high up immediately after its origin, and before it divides into cutaneous and muscular portions. These are distributed to the two parts of its bipennate belly, entering its deep surface immediately after dividing extramuscularly into two or three twigs, the points of entrance being at levels varying from 4 to 8 cm. below the styloid process of the fibula, i.e. in the distal half of the proximal fourth of the leg measured from the styloid process to tip of lateral malleolus. Other twigs reach the deep part of the muscle from the muscular division. The *peronæus brevis* receives its nerves on its superficial face. A nerve is given off at a varying level under the peronæus longus which enters the muscle a little below the middle of the leg. The hilum extends from about 18 cm. to about 22 cm. from the styloid process of the fibula. The muscular division of the nerve is then continued downwards and can generally be followed on the surface of the peronæus brevis below the level of the longus. It here gives off some branches to the muscle and also gives a branch to the extensor quinti digiti brevis (peronæus quartus) when that muscle is present. In some cases, as already stated, it has been followed still further under the tendons of the peroneal muscles on to the dorsum of the foot to end in the extensor quarti digiti.

The Muscles of the Posterior Region

The muscles of the back of the leg occupying the posterior fascial compartment consist of a superficial group inserted into the calcaneus, and a deep group, covered in by a deep fascia, which for the most part descend to the sole of the foot.

The **superficial group** consists of three muscles. Two of these, the gastrocnemius and soleus, are of large size and form the bulk of the calf of the leg. They descend, the gastrocnemius lying on the surface of the soleus, to be inserted by a common tendon, the tendo Achillis. The third muscle, the plantaris, is a very long slender slip which passes down between the other two to reach the calcaneus.

The flexor-pronator mass in the leg has undergone great differentiation in consequence partly of the fixation of the bones, but chiefly as the result of the specialisation of the tibio-tarsal joint. In the primitive tetrapod a strong set of muscles was required to extend the foot at the ankle, so as to raise the weight of the body from the ground, and to give the forward push in progression.

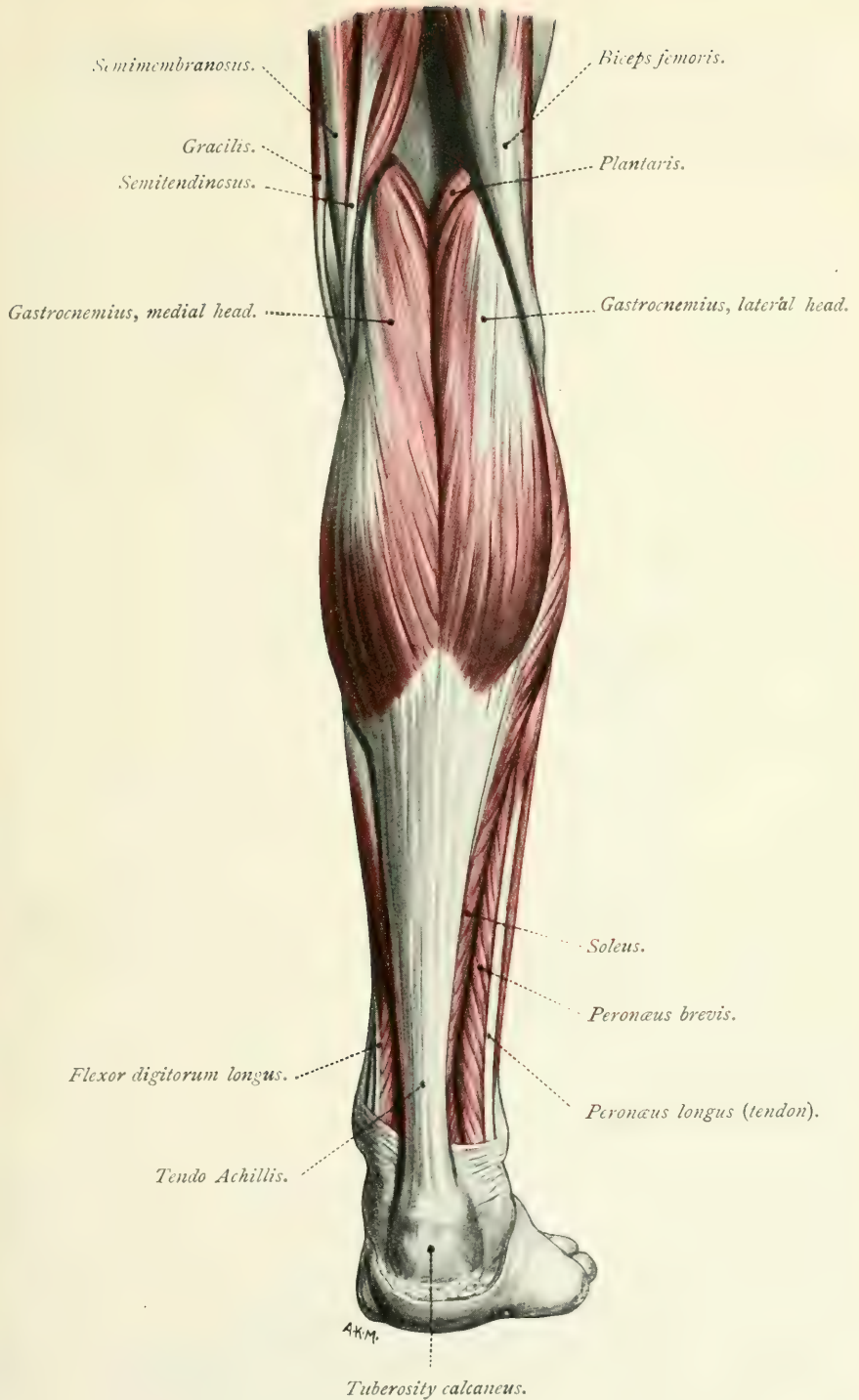


FIG. 83.—MUSCLES OF CALF; SUPERFICIAL LAYER.

This has been provided by the fibular marginal muscle (lateral gastrocnemius and soleus) attached to the os fibulare (calcaneus), and the heel process has been developed to provide the necessary leverage. The lateral gastrocnemius and soleus are so largely developed that they have come to overlap the digital and tibial tarsal flexors and the popliteus. This has been carried in man, by the extension of the attachment of the soleus to the tibia, further than in any other form, and with the medial expansion of the muscles and consequent alteration in the axis of their pull the calcaneus has been displaced more directly under the talus.

M. Gastrocnemius (figs. 83, 84, 85).—The gastrocnemius muscle consists of two large heads which spring from the distal end of the femur, and end about the middle of the leg in a common tendon. The lateral head arises from a depression on the outer face of the lateral condyle above the tuberosity (epicondyle), and from the hinder surface of the femur immediately above the condyle. The medial head springs by its medial and more superficial fibres from an impression on the upper part of the medial condyle, close behind the adductor tubercle, from the lower end of the supracondylar ridge, from the capsule covering the medial condyle, and, by a system of deeper fibres, from an adjoining roughened or raised part of the popliteal surface of the femur which extends on to the diaphysis.

The marginal part of each origin consists of a strong tendon which is attached to the impression on the condyle, and spreads out as it descends over the surface of the head. The central part of each head, on the other hand, arises by short tendinous fibres which are succeeded by a prominent fleshy mass extending along the part of the head next to the middle line of the limb. The two heads enlarge downwards as fresh fibres are added from the superficial tendons. The adjacent borders then converge and meet, but do not join, being separated superficially by a longitudinal groove, and deeply by a thin tendinous band which is seen when the fleshy fibres are drawn aside. The muscular bundles are short and incline obliquely forwards to end on the posterior surface of the inferior tendon. This is broad and aponeurotic as it occupies the deep face of the muscle, but becomes narrower and thicker as it proceeds downwards to be incorporated with the subjacent tendon of the soleus as the tendo Achillis.

The lower edge of each muscular part is convex downwards, and the medial head, besides being broader and thicker, also descends lower than the lateral head. A synovial bursa, which may communicate with the knee-joint, lies beneath the medial head of origin and separates it from the tendon of the semimembranosus muscle. A second smaller bursa which may also open into the joint usually intervenes between the tendon and the femur near its origin. A similar bursa may be present under the tendon of the lateral head. In this head in about 15 per cent. of cases a sesamoid fibro-cartilage or bone is met with. A similar sesamoid may occur in the medial head, but it is very rare.

Relations.—The heads of the gastrocnemius muscle form the inferior boundaries of the popliteal space, and are placed between the hamstring muscles. At its origin the medial head is overlapped by the semimembranosus and the lateral head by the biceps. Between the biceps and the lateral head the lateral popliteal (common peroneal) nerve is lodged. The posterior surface of the muscle is covered by a thin lamella of fascia; the deep surface lies over the popliteus, plantaris, and soleus muscles, and the popliteal vessels and the medial popliteal nerve. The small saphenous vein is placed over the muscle, and the tibial communicating nerve descends in the interval between the two heads.

M. Soleus (figs. 83, 84).—The soleus muscle, as its name indicates, has the form of a thick flat plate. It lies under the gastrocnemius, and arises from the posterior surface of the head and the proximal third of the shaft of the fibula; from the oblique line and the medial border of the tibia as far as the middle of the bone; and lastly from a fibrous arch which extends between the tibia and fibula over the

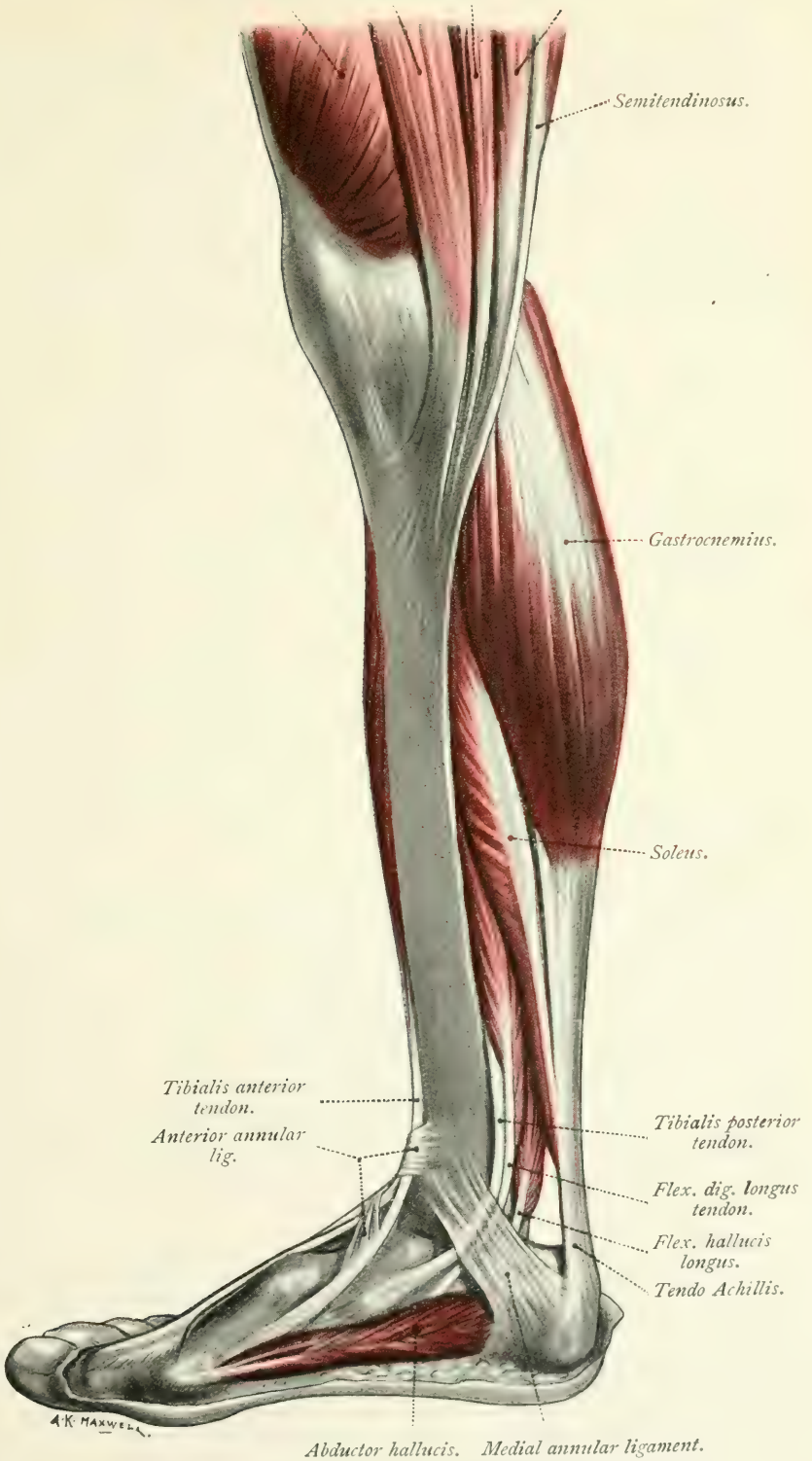


FIG. 84.—MUSCLES OF THE LEG AND FOOT FROM THE MEDIAL SIDE.

popliteal vessels and tibial nerve. Almost the whole of its posterior surface is covered by an aponeurosis, on which the tendinous deep surface of the gastrocnemius glides. Becoming narrower and thicker at the lower extremity of the muscle this aponeurosis is prolonged into the tendon of insertion which forms the deeper and larger part of the tendo Achillis. On each side of the tendon, and below the level where it is joined by the gastrocnemius tendon, numerous short fleshy fasciculi are seen joining the deep surface of the tendo Achillis to within a short distance of the heel. The deep or anterior surface of the muscle is formed, in large part, of a mass of fasciculi which converge in bipennate fashion on a tendinous raphe or septum which is continued up from the tendon of insertion into the substance of the muscle. On each side of the bipenniform mass are seen the margins of two tendinous intersections which occupy the belly of the muscle and give origin to the great mass of the fleshy fasciculi.

If the bipenniform portion of the muscle be dissected carefully off the deep face of the muscle it will be seen that two tendinous intersections descend on the surface of the muscle exposed, one from the fibula and the other from the oblique line on the tibia and the arch over the popliteal vessels. The margins of these lamellæ appear free on the deep face of the muscle, in its undisturbed state, on each side of the bipenniform portion, and more or less of the lamellæ is exposed according to the extent of the bipenniform mass. The two lamellæ are inclined obliquely towards the middle line of the muscle but do not join. From the dorsal aspect of these intersections the great mass of the muscular fasciculi arise; they are numerous and short and end on the aponeurosis which covers the posterior surface of the muscle. To the muscle thus constituted, and as it occurs in the anthropoids, there is added the bipenniform mass as a peculiarly human feature. The feathered fasciculi arise from the deep or anterior faces of the intersections and occupy the angle which these form with one another. They converge on a tendinous raphe or septum which runs up from the tendon of insertion, and intervenes between the medial edges of the tendinous intersections. In the quite typical case this septum is placed in the middle line of the muscle, but very often it is on the tibial side and runs obliquely towards the tibial margin. In this case the bipenniform mass is eccentric, and a considerable part of the fibular intersection is exposed. In rare cases the raphe-like median septum may broaden out into a band, the edges of which extend on the anterior face of the feathered fasciculi, and sometimes a second sagittal intersection is seen on the fibular side of the muscle, due to a fold, as it were, of the main fibular intersection.

The tendo Achillis (fig. 84), the thickest and strongest tendon in the body, is formed by the union of the flat tendons of the gastrocnemius and soleus muscles which thus form the triceps muscle of the calf. Broad at its commencement near the middle of the leg, the tendon contracts and becomes thicker to within a short distance of the heel, where it again expands to be inserted into the middle part of the posterior surface of the tuberosity of the calcaneus. The narrowing of the tendo Achillis is due to the fact that the tendinous fibres from the two heads of the gastrocnemius cross one another in a rope-like fashion, the medial fibres passing superficial to the lateral; this is a reminiscence of the condition found in certain lower mammals in which the two portions of the muscle are independent and cross one another. A synovial bursa is interposed between the tendon and the upper part of the tuberosity.

Relations. The soleus rests upon the flexor hallucis longus, flexor digitorum longus and ibialis posterior muscles together with the posterior tibial vessels and nerve. It is separated from these structures, however, by a deep fascial septum. According to Poirier there is generally a small and ill-defined bursa over the tendo Achillis between it and the overlying fascia.

Varieties of the Gastrocnemius and Soleus Muscles.—The gastrocnemius must be considered, in view of its phylogenetic history and development in the human subject, a muscle of the fibular side of the leg. This is quite certainly true of the lateral head and also of the soleus. The latter appears first in the lower mammals and is a derivative of the lateral head of the gastrocnemius, is in short its fibular portion. The medial head is probably to be regarded as a medial extension from the fibular head. The relation to the plantaris suggests this, but it must be noticed that the medial head is present far down in the vertebrate scale. The gastro-

nemius is not infrequently joined by a separate fasciculus (*gastrocnemius tertius*) arising from some part of the popliteal surface of the femur. It may merge with the two heads at their junction or separately with one or other head, or with the fascia under the muscle; it has been seen passing between the popliteal artery and nerve. Absence of the outer head and its reduction to a fibrous cord have been observed. In some cases the two heads may remain apart close to their insertions on the calcaneus, and it occasionally occurs that the muscle is quite separate from the soleus. Another variety, which comes like the last two into the category of retrogressive variations, is the failure of the tibial head of the soleus. In certain lower primates the soleus receives fibres from the lateral tibial condyle and the surface below it, but in the gorilla only is there a tibial head in the human sense though its attachment is less extensive than in man. An accessory muscular slip arising from the soleal line or detached from the muscle lower down is occasionally seen. It usually ends on the tendo Achillis, but sometimes has a separate attachment to the calcaneus or the tibial collateral ligament of the ankle.

M. Plantaris (figs. 83, 85).—This muscle like its homologue in the arm is variable and frequently absent. It arises in close association with the lateral head of the gastrocnemius from the femur immediately above the lateral condyle and from the posterior ligament of the knee-joint. The muscular belly which is only some 3 to 8 cm. in length ends on a long slender tendon. This lies between the gastrocnemius and soleus muscles, but inclining medianwards as it descends, and becoming free of the muscles, it runs along the medial border of the tendo Achillis to reach the calcaneus, where it is inserted alongside that tendon.

Varieties.—The plantaris varies in its mode of origin and still more frequently in its mode of insertion. It may arise by an accessory head which may co-exist with the normal origin, making the muscle bipical; it may spring from the fascia of the popliteus muscle, from the origin of the lateral head of the gastrocnemius, from the fibula, or from the fascia of the leg. Below it frequently joins the tendo Achillis, or ends on the fascia of the leg, or on the tibial collateral ligament of the ankle. Its tendon is sometimes enclosed in the lower part of the tendo Achillis; it may give a slip to the plantar fascia.

Like the palmaris longus this muscle, which is little developed in man, is the remains of the superficial layer of the original common flexor of the digits (see p. 27). In many animals it is of large size, and is continued over the calcaneus into the plantar fascia. In man it is separated, as it were, into two parts, a proximal and a distal, by the great prominence of the heel. The same holds for the anthropoids in which it is frequently absent as in man.

Nerves to the Muscles of Superficial Group.—The gastrocnemius, soleus, and plantaris are supplied by branches of the medial popliteal (tibial) nerve given off in the popliteal space. The *gastrocnemius* is supplied by two branches, one for each head, each of which divides into two or three twigs which enter the muscle substance high up in the proximal fifth. The central twigs of each branch can be traced through the muscle substance as far as the tendon of insertion. They give off branches to the distal part of the muscle. The *soleus* receives two branches, one for each of its layers; the superficial or posterior branch, sometimes arising in common with the nerve to the lateral part of the gastrocnemius, enters the superficial surface of the muscle near its origin and after giving a few twigs to its uppermost part, ends in two branches, one for each half of the muscle. The deep or anterior branch comes off lower down; it passes deep to the plantaris and reaching the deep aspect of the tendinous intersection gives two main twigs to the two portions of the deep bipenniform section of the muscle. The *plantaris* receives its branch from the lateral popliteal nerve opposite the lower border of the lateral condyle; it enters the muscle in the form of three or four twigs.

The **deep group** of the posterior muscles of the leg is in close contact with the bones; it includes the popliteus, flexor hallucis longus, flexor digitorum longus, and tibialis posterior.

M. Popliteus (fig. 85).—The popliteus muscle is a short muscle deeply placed below the knee, and covered by a strong fascia largely derived from the tendon of the semimembranosus. Triangular in shape it arises by a strong rounded tendon, about 2.5 cm. in length, from the lower part of the groove on the outer surface of the lateral condyle of the femur, within the fibular collateral ligament and capsule of the knee-joint. It is in contact with the lateral semilunar fibro-

cartilage, and receives additional fibres from the posterior ligament of the joint. The muscular fasciculi diverge as they pass downwards and medially, and are inserted into the triangular surface of the tibia above the soleal line, and into the fascia covering the muscle. The tendon of origin occupies the groove on the femoral condyle only in the flexed position of the joint; in the extended position it rests in a notch on the lower border of the condyle. The synovial membrane of the knee-joint sends a prolongation between the tendon and the back of the lateral condyle of the tibia.

Varieties.—The popliteus represents the pronator element of the flexor-pronator mass, and corresponds with the upper head of the pronator teres of the arm. It was originally a fibulo-tibial or interosseous muscle, of which the fibular origin has been replaced by a secondary femoral attachment. The course of the nerve to the muscle round the distal border to reach the deep surface is explained by the fact that in development the muscle fibres wander distally, rolling themselves as it were round the lower border in such fashion that the distal part receiving the nerve is removed to the deep surface and becomes the anterior lamella of the muscle. A rare variation is the presence of a second head, or accessory slip, which arises from the upper and posterior part of the lateral condyle of the femur on the inner side of the plantaris, from the lateral head of the gastrocnemius or the sesamoid bone contained therein, and slightly in some cases from the posterior ligament of the knee-joint, and is inserted into the inner end of the oblique line and the medial border of the tibia along with the medial fibres of the popliteus. In crossing the popliteal space it may lie in front or behind the vessels. In one instance a sesamoid was observed by Macalister in the tendon of the popliteus. The *peroneo-tibialis* is a small muscle arising from the medial side of the head of the fibula which crosses the interosseous space deep to the popliteus, to be inserted into the upper end of the soleal line, or into the tendinous arch of the soleus. It is present normally in most of the lower primates, and in the chimpanzee. It is possible that this may correspond to the second head of the pronator teres.

The three remaining muscles of this group are bound down together by the deep fascia, which extends from the tibia to the fibula, and separates them from the soleus. The tibialis posterior occupies the middle position, and is overlapped on the medial side by the flexor digitorum longus which arises from the tibia, and on the lateral side by the flexor hallucis longus which arises from the fibula.

M. Flexor Digitorum Longus (figs. 85, 87).—The long flexor or *flexor perforans* is the medial muscle of the deep group. It arises from the medial portion of the posterior surface of the tibia, extending over the middle two-fourths of the length of the bone, and likewise receives some fibres from an aponeurosis which separates it from the tibialis posterior. This aponeurosis is common to the flexor digitorum longus and flexor hallucis longus and connects them together over the tibialis posterior. It is attached to the tibia below the oblique line, along the central ridge on the posterior surface down to the distal part of that surface, and when well developed spreads proximally over the tibialis posterior to the medial border of the fibula. The tendon appears on the posterior and lateral border of the muscle, and becoming free of fleshy fibres, descends behind the tibial malleolus invested in a distinct fibrous and synovial sheath. From the malleolus it is directed obliquely forwards and outwards into the sole of the foot, and crosses superficially the tendon of the flexor hallucis longus, to which it is connected by a tendinous slip. It finally divides into four parts, which pass forwards to be inserted into the terminal phalanges of the four smaller toes. Each digital tendon enters a fibrous sheath on the toe to which it belongs, perforates the corresponding tendon of the short flexor, is invested with synovial membrane, and connected by vincula to the phalanges; the whole arrangement being essentially the same as that which has already been described in the fingers (see p. 161).

The belly rests upon the tibia and tibialis posterior, and crosses obliquely behind the latter in the distal third of the leg. It is covered in the upper part of the leg by the soleus, and inferiorly

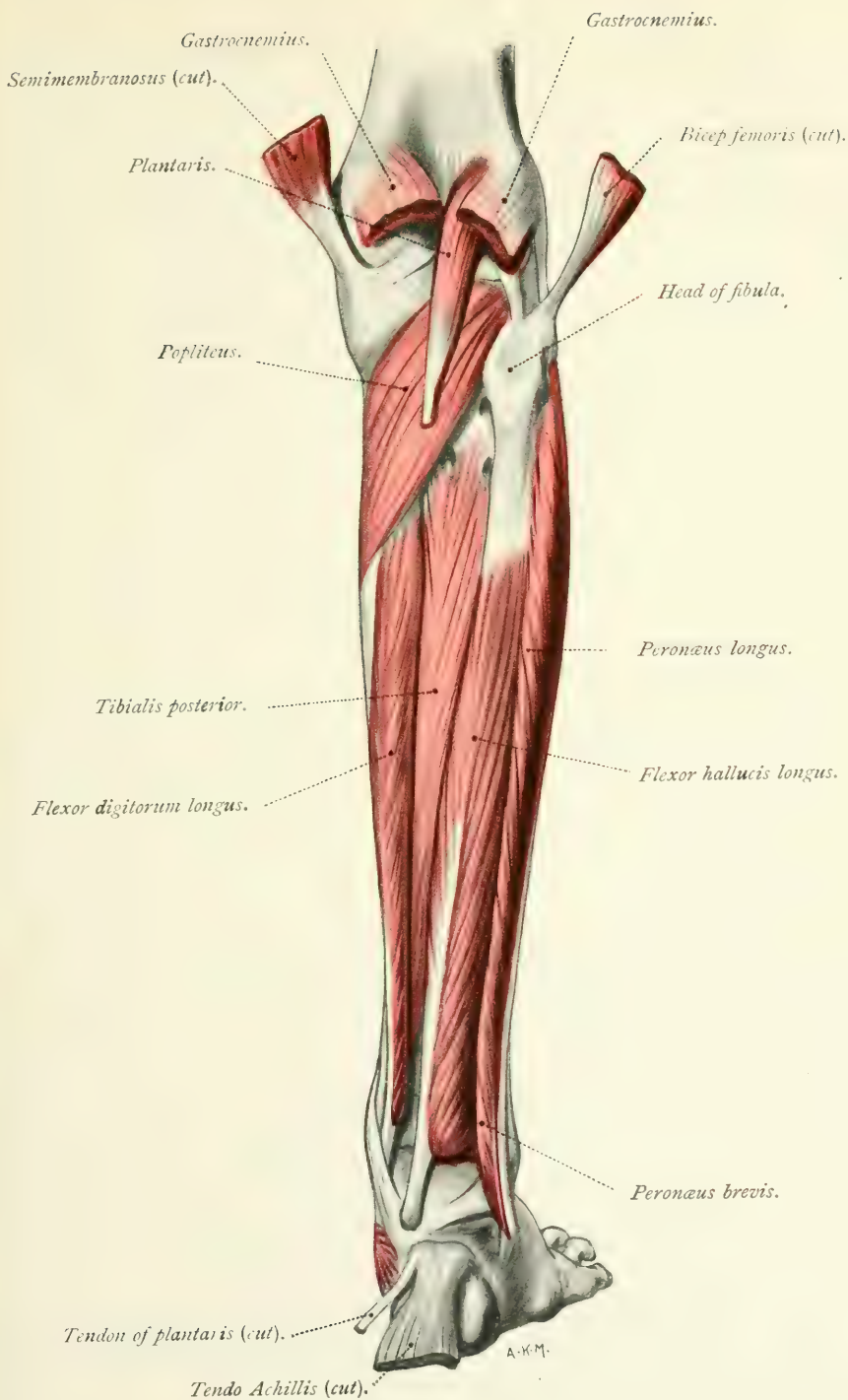


FIG. 85.—MUSCLES OF CALF; DEEP LAYER.

by the deep crural layer of the fascia. Upon it lie the posterior tibial vessels and the accompanying nerve.

Intimately connected with the tendon of the long flexor of the toes are the flexor accessorius and the lumbrical muscles. These, although they are situated in the sole of the foot, may be most conveniently described in this place.

The **flexor accessorius**, or **quadratus plantæ** (fig. 87), arises by two heads which diverge behind and leave exposed between them a portion of the long plantar (calcaneo-cuboid) ligament. The lateral head, flat, narrow and tendinous, is closely connected with the outer part of the long plantar ligament on the under aspect of the calcaneus as far forward as the cuboid, and extends backwards to be attached to the lateral face of the calcaneus just in front of the lateral tubercle on the tuberosity. The medial head, which is the larger of the two, is fleshy, and extends on to the medial surface of the calcaneus. The muscular mass formed by the union of the two heads is inserted into the lateral and upper surfaces of the tendon of the flexor digitorum longus.

The deep portion of the muscle also gives slips to a variable number of the digital tendons of the long flexor, most frequently to those of the second, third, and fourth toes. A slip is sometimes given to the fifth toe which replaces the tendon from the short flexor. Further a slip passes to the tendinous connexion between the tendon of the flexor hallucis longus and that of the flexor digitorum longus. More rarely a slip joins the tendon of the great toe itself, and the muscle has been seen to end entirely on this tendon. The lateral head is often wanting, and absence of the whole muscle is on record.

Mm. Lumbricales (fig. 87).—The lumbrical muscles of the foot agree very closely with those of the hand. Four in number, they arise from the tendons of the flexor digitorum longus at their point of division, each being attached to two tendons, with the exception of the first, which is attached to the tibial—great toe—side of the tendon to the second toe. They run forwards in the interdigital clefts, each muscle ending in a delicate tendon, which, passing on the tibial side of the digit to which it belongs, is inserted into the expansion of the extensor tendon, or frequently, in part or in whole, into the base of the first phalanx.

Varieties.—There are sometimes small bursæ between the tendons and the bases of the first phalanges. Absence of one or more of the lumbrical muscles has been observed; also doubling of the third and fourth. Various abnormal attachments have been noted; the second, third, or fourth may be attached to the short instead of to the long flexor tendon, and the first may spring from the tendon of the tibialis posterior.

M. Flexor Hallucis Longus (figs. 85, 87).—The long flexor of the great toe arises from the distal two-thirds of the posterior surface of the fibula, from the intermuscular septum between it and the peronæi, and from the aponeurosis which is common to it and the flexor digitorum longus and covers the tibialis posterior. The muscular fasciculi converge bipennately on a tendon which appears on the posterior face of the muscle in the distal third of the leg, and becomes clear of fleshy fibres at the level of the ankle-joint. Here it runs in grooves, on the back of the tibia, on the back of the talus, and on the under aspect of the sustentaculum tali respectively, being bound down to these bones by a fibrous sheath lined by synovial membrane. Thence, passing forwards and medially in the sole of the foot, it gives off a slip to the tendon of the flexor digitorum longus by which it is crossed, and proceeds in a fibrous sheath over the first phalanx of the great toe to be inserted into the base of the terminal phalanx.

The muscle is concealed for the most part by the soleus, a small part only on the lateral side of the tendo Achillis being covered by the fascia of the leg. Laterally it is in contact with the

peronæi, medially with the posterior tibial vessels and nerves. It rests upon the fibula and tibialis posterior, and conceals the peroneal vessels.

Varieties of the Long Flexors.—The connexion between the tendon of the long flexor of the great toe and that of the long flexor of the toes is constant, but the mode of union is very variable. In almost every case a slip is given from the flexor hallucis to the flexor digitorum, but frequently (1 in 5) an additional slip proceeds, in the reverse way, from flexor digitorum to flexor hallucis. Complete separation of the tendons is very rare; it is normal in the orang and chimpanzee, although a similar arrangement to that seen in man prevails in most other primates. The slip of connexion from the flexor hallucis is distributed in over 50 per cent. of cases to the tendons of the second and third toes; less frequently it passes to the second toe alone, or to the second, third, and fourth, or rarely to all four outer toes.

In the normal arrangement of the long flexor muscles there are several features which indicate that there is not the same degree of differentiation as there is between the corresponding muscles in the arm. Both flexors are closely connected in the leg, and in the foot the flexor of the great toe does not act on the great toe alone, but sends slips to the others also. In a few instances, however, progressive variations have been observed in the form of special muscular slips for the second toe and the fifth toe. It is possible that the flexor fibularis (hallucis longus) was the original long flexor of the toes and that the flexor tibialis (digitorum longus) was secondarily separated off from it. Supplementary fasciculi of varying size have been described arising from the tibia, tibialis posterior, the fibula, or the fascia of the leg, and joining the tendon of the flexor digitorum longus at the ankle. A slip has also been observed arising from the fascia over the flexor digitorum and joining the tendon of the flexor hallucis longus in the sole of the foot.

A more frequent variation is the *flexor accessorius longus*. It arises in the leg in a variety of ways, from the tibia or fibula or from both bones, from the deep fascia or from one of the muscles, and ends in a tendon, which after passing under the median annular ligament, joins the accessorius in the sole of the foot. The flexor accessorius proper probably represents one of the divisions of the deep flexor layer in the leg of urodeles (Eisler) and the tarsal head of the deep flexor in lizards (Rabl).

The *peroneo-calcaneus internus* is the name given to a slip of rare occurrence and belonging to the same general category as the last. It arises from the back of the fibula, below and outside the flexor hallucis longus, and passes with the tendon of that muscle in the groove under the sustentaculum tali, to be inserted into the calcaneus, or the tendon of the flexor hallucis.

M. Tibialis Posterior (figs. 84, 85).—Deeply placed beneath the two long flexor muscles, the posterior tibial muscle arises from the interosseous membrane and both bones of the leg. The origin from the tibia extends over the outer portion of the posterior surface of the bone, from the superior tibio-fibular articulation to the middle of the shaft; the fibular origin covers the whole of the postero-medial surface of the fibula. A few fasciculi spring from the aponeurosis covering the muscle. The fleshy fibres converge upon a tendon which, commencing in the centre of the muscle, descends along its medial border, and passes beneath the tendon of the flexor digitorum longus to reach the back of the medial malleolus. Here it rests in a distinct groove and is contained in a fibrous sheath lined by synovial membrane. It then inclines forwards over the tibial collateral ligament of the ankle, passes under cover of the abductor hallucis, and reaches the under aspect of the inferior calcaneo-navicular ligament. Here it becomes flattened and contains in its substance a sesamoid fibro-cartilage, or sometimes a bone. Beyond this point a strong fasciculus is given off from its antero-medial border to the tuberosity of the navicular bone and a much smaller, thinner process backwards and outwards to the sustentaculum tali. The tendon is then continued obliquely across the sole of the foot, sending offsets to the three cuneiform bones, to the cuboid, and to the bases of the second, third, and fourth metatarsals. The tendon is connected to some extent with the sheath of the peronæus longus tendon. Sometimes the tendons are united by bands.

Varieties.—These are few and rare. Le Double described two cases in which the muscle consisted of two portions. The accessory part was separately inserted in the sole of the foot. The muscle described under the name of *tibialis secundus* is included by Le Double in the same category. It arises from the posterior aspect of the tibia below the tibialis posterior, and closely

accompanying its tendon to the level of the ankle is inserted into the lower portion of the anterior annular ligament. A similar slip ending on the anterior wall of the capsule of the ankle-joint (*tensor capsuli tibio-tarsalis anterior*) is included by Le Double among the variants of the long accessory muscle. It seems reasonable to regard all these short slips described under this head, or under the flexor accessorius muscle, whatever their actual insertion may be, as remnants of a deep layer of the flexor sheet which normally is represented only by the accessorius.

Nerves to the Deep Layer of Muscles of the Leg.—All the muscles in this group are supplied from the medial popliteal or tibial nerve, either before or after it leaves the popliteal space. The highest nerve of the series is that for the *popliteus*. It comes off opposite about the middle of the posterior aspect of the muscle, runs down to its distal border, and then turns upwards again to reach its anterior or deep surface at a point 10 cm., approximately, from the adductor tubercle. It divides into two sets of twigs, the upper ascending towards the origin, and the lower descending towards the insertion of the muscle. The nerve to the *flexor digitorum longus* leaves the trunk immediately below the preceding opposite the highest point of the origin of the muscle from the tibia. It is directed forwards, downwards, and inwards, and divides into two branches, one short branch for the upper half of the muscle, to which it gives several twigs, and a long branch which runs along the lateral border of the muscle, and gives some twigs to it before finally entering the muscle substance in which it can be traced down to the tendon. The upper branch sinks into the muscle along an entrance line 15 to 16 cm. from the adductor tubercle; the lower branch 19 to 23 cm. from the same point. The nerve to the *flexor hallucis longus* also comes off very high up, just below the nerve to the flexor digitorum, and likewise divides into two, a smaller branch which enters the upper part of the muscle on its superficial aspect, and a larger which enters on its deep surface. It has a long course and can be traced down to the tendon. Another slender twig may be given to the upper part of the flexor hallucis from one of the nerves to the tibialis posterior. It lies directly upon the peroneal artery. The entrance lines of the two main branches are placed 24 to 29 cm. and 25 to 34 cm. respectively from the adductor tubercle. The *tibialis posterior* receives two branches from the main trunk which come off close to the others just described. The upper branch divides into twigs for the tibial and fibular parts of the muscle at its proximal part. The lower and larger branch runs distally upon the peroneal artery, gives several twigs to the tibialis posterior, and may give also a terminal branch into the flexor hallucis longus. The entrance lines lie at the following approximate distances from the adductor tubercle: upper branches, fibular side, 12 to 18 cm.; tibial side, 13 to 19 cm.; long lower branch, 16 to 27 cm.

THE MUSCLES AND FASCIÆ OF THE FOOT

Fasciæ.—The **fascia of the dorsum of the foot** is reduced to a thin membrane prolonged from the anterior annular ligament over the extensor tendons. It is continued round the borders of the foot into the fascia of the sole. Beneath the tendons a very thin fascial layer covers the extensor brevis and the dorsal artery and nerve of the foot, while beneath these again is a delicate layer which covers the interossei muscles.

The **subcutaneous fascia of the sole** resembles that of the palm of the hand. It forms a thick cushion, especially over the bony prominences, and consists mainly of small lobules of fatty tissue bound down by numerous fibrous strands which pass vertically from the skin to the deep fascia. Small bursæ are often found over the heel and the heads of the first and fifth metatarsal bones.

The **deep fascia of the sole** consists of a central and two lateral portions, which are marked off from each other by superficial grooves, indicating the position of intermuscular septa.

The *central portion* is composed of dense white glistening fibres, the greater number of which run longitudinally from the heel to the roots of the toes. It is narrow and thick behind where it is attached to the medial tubercle of the calcaneus immediately below the origin of the flexor digitorum brevis, with which muscle it is intimately connected for some distance in front of the heel. It becomes broader and thinner as it extends forwards, and some distance behind the heads of the metatarsal bones it divides into five processes, one passing to each of the toes. Just behind the metatarso-phalangeal joint, each of these processes

is resolved into a central and two lateral sets of fibres. The central fibres are continued forwards to the digital sheath, the superficial cutaneous interdigital ligament and the skin of the toes, while the lateral fibres form two deep processes, one on each side of the flexor tendons, which end on the deep transverse metatarsal ligament. The arrangement is identical in all essential respects with that of the corresponding parts of the palmar aponeurosis. In the intervals between the processes a thin membrane composed of transverse fibres covers the lumbrical muscles and the digital nerves. There is no such distinct transverse band of fibres as the superficial transverse metacarpal ligament of the hand. In the folds of skin limiting the interdigital clefts a thin band of fibres constitutes a *superficial transverse ligament of the toes*, or *interdigital ligament* identical with that in the hand, save that it connects all five digits.

From the borders of the central portion of the plantar fascia some of the longitudinal fibres spread medially and laterally, while deep processes are given off to form two strong intermuscular septa. These separate the flexor digitorum brevis from the abductor hallucis on one side, and the abductor minimi digiti on the other, and give partial origin to each of these muscles.

The *medial portion* of the plantar fascia invests the abductor hallucis. It is thin and loose, purely fascial in character, but receives in front a fairly strong accession of fibres from the central aponeurosis. It is continuous round the medial border of the foot with the dorsal fascia and with the lower fibres of the medial annular ligament. The *lateral portion* covers the abductor minimi digiti. It is much stronger, and forms a particularly thick aponeurotic band between the lateral tubercle of the calcaneus and the tuberosity of the fifth metatarsal bone. It sends in most cases a thin prolongation forwards over the insertion of the abductor and short muscles of the little toe, which may be continued under the lateral lumbrical muscle to end on the capsule of the metatarso-phalangeal joint of the fourth toe.

The plantar aponeurosis *sensu stricto* consists of two parts, a tibial distributed to the five toes, and a fibular, the lateral band just described. In lower primates the tibial part is slightly developed or absent, while the lateral band is strong and receives from above the tendon of the plantaris in some forms. The great strength of the plantar aponeurosis in man is to be correlated with the function of the foot. In the lower primates it is slightly developed when the foot functions as a grasping organ, but is stronger when it is used in walking on the ground.

A deep layer of fascia covers the interossei muscles, stretching between the first and fifth metatarsals. It is continuous in front with the transverse metatarsal ligament, and loses itself behind on the plantar ligaments.

Muscles of the Sole of the Foot

The muscles of the sole of the foot are lodged in three fascial compartments, a central and two lateral, separated from one another by two intermuscular septa, but it is more convenient to describe them in four layers as they are met with in the course of dissection.

The *first layer of muscles* includes the short flexor of the toes and the abductors of the great and little toes. They are derived from the superficial short flexor mass in the sole of the foot (see p. 28).

M. Flexor Digitorum Brevis (Flexor Perforatus) (fig. 86).—This muscle is placed directly under the plantar aponeurosis, and between the two abductors.

It arises from the medial tubercle of the calcaneus, from the deep surface of the plantar aponeurosis for about 5 cm. in front of this, and from the intermuscular septa on each side of it. The muscular fasciculi become divided into four slips which end upon four slender tendons which are attached to the sides of the second phalanges of the four outer toes. Each tendon divides prior to its insertion and gives passage to a tendon of the long flexor, in a manner precisely similar to the arrangement of the flexor sublimis and flexor profundus muscles of the hand.

Varieties.—The slip of the flexor brevis to the little toe is frequently defective or wanting. It may be present but fail to reach the toe, ending on the fascia, or may reach the toe but not show the normal perforation. It may arise separately from the fibular band of the plantar aponeurosis. It is entirely absent in about 21 per cent. of cases, but may be replaced by a small fusiform muscle arising from the long flexor tendon, with occasional additional attachments to the medial tubercle of the calcaneus, the lateral intermuscular septum, or the accessorius. This slip represents part of the deep head which occurs in monotremes, marsupials, and all primates below man. In other mammals the superficial head supplies the perforated tendons, but in lemurs and all new world and old world monkeys it is reduced to a single slip for the second digit, with a second slip to the third in a few forms. In the Simiidae there are two slips as a rule, the fourth and fifth digits receiving their perforated tendons from the deep head. In rare cases this condition is reverted to in man, both fourth and fifth toes receiving deep slips. The deep head may also be represented in another and more vestigial form by slips which pass from the deep tendon to reinforce or replace the tendons of the short flexor.

M. Abductor Hallucis (fig. 86).—The abductor muscle of the great toe arises from the medial part of the medial tubercle of the tuberosity of the calcaneus, from the medial annular ligament, the medial intermuscular septum, and also by some accessory fibres from the navicular bone. The fleshy fasciculi end upon a tendon which takes form on the deep face of the belly, and appears on the lateral face of the muscle about the level of the first cuneiform bone. Thence it is continued forwards as a flat band to be attached to the medial side of the base of the first phalanx of the great toe, and partly also, along with the medial head of the flexor brevis, into the medial sesamoid bone. A bursa may exist between the tendon and the head of the first metatarsal bone. Lovell and Tanner describe also a small bursa at the level of the proximal end of the first metatarsal which is present when the slips of insertion are separate from one another.

Varieties.—The abductor hallucis occasionally sends a slip to the base of the first phalanx of the second toe. Its tendon of insertion is sometimes joined by a muscular slip springing from the skin on the inner border of the foot somewhat in front of the inner ankle: but this is not so frequent as the cutaneous slip of the corresponding muscle of the hand. According to Poirier the abductor is sometimes connected with the anterior annular ligament by a tendinous band, in which a small sesamoid may occur.

M. Abductor Minimi Digiti (fig. 86).—The abductor of the little toe has a wide origin behind, arising from the front of both tubercles on the under surface of the calcaneus, from the lateral intermuscular septum, and from the deep surface of the fibular band of the plantar aponeurosis. The fasciculi end upon a flattened tendon, which appears free on the plantar aspect of the muscle, glides on a smooth depression on the plantar face of the base of the fifth metatarsal bone, and is inserted into the lateral side of the base of the first phalanx of the little toe. Fleshy fibres continue to be implanted on the dorsal face of the tendon as far as the metatarso-phalangeal joint. Between the tendon and the base of the fifth metatarsal bone there is generally a small bursal sac. Two other minute bursæ have been described, one between the muscle and the sesamoid bone in the peronæus longus, and a second of occasional occurrence between the tendon and the head of the fifth metatarsal bone.

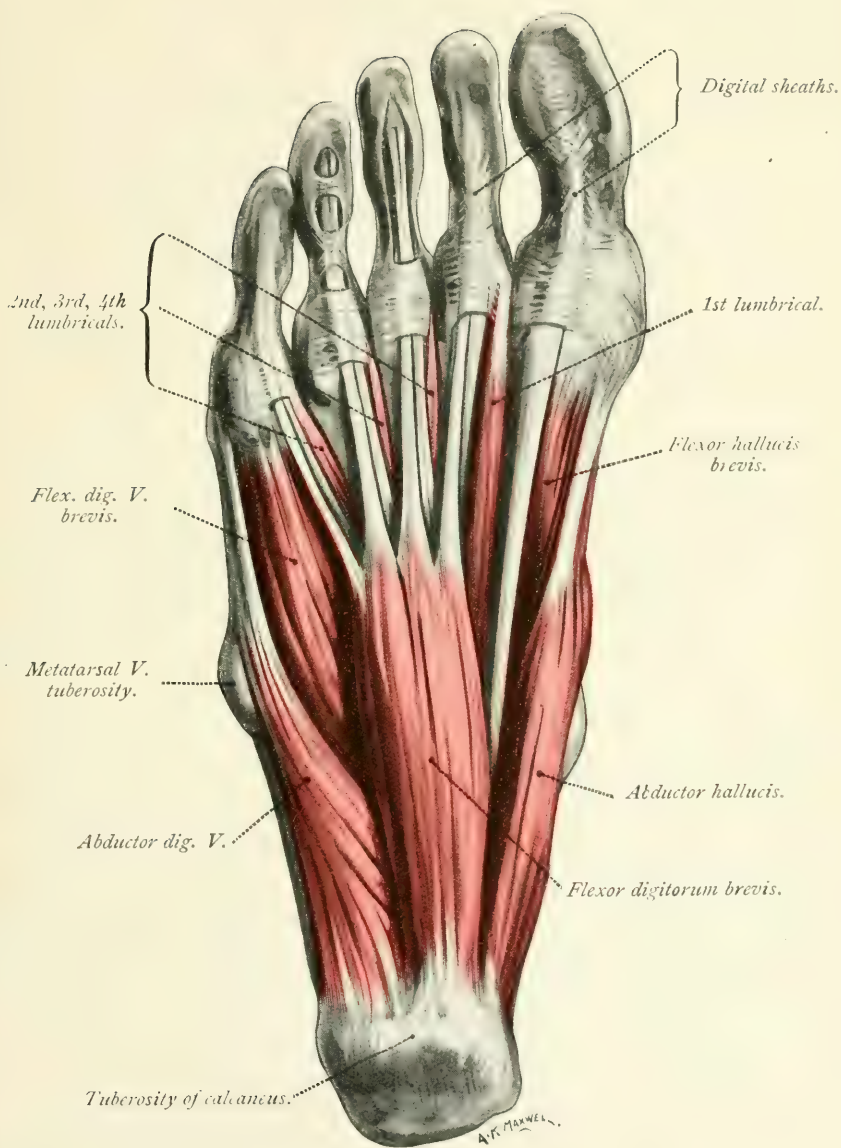


FIG. 86.—MUSCLES OF SOLE OF FOOT; FIRST LAYER.

Varieties.—An additional slip of origin from the base of the fifth metatarsal bone is sometimes present. On the other hand, a part of the muscle may be inserted upon the base of the metatarsal bone. These fibres may form a small independent muscle, *abductor ossis metatarsi quinti digiti*, which arises from the lateral tubercle of the calcaneus, and is inserted into the tuberosity of the fifth metatarsal bone in common with or beneath the outer margin of the calcaneo-metatarsal band of the plantar fascia. It may be adherent to the abductor of the little toe, and has been seen to extend to the middle or even the anterior part of the metatarsal bone. It is common, occurring in over 40 per cent. of cases.

Relations.—The three muscles of the first layer are covered each by its own division of the plantar fascia, and their position is defined by the sulci corresponding to the intermuscular septa. The deep surface of the abductor hallucis is in contact with the tendon of the tibialis posterior, the long flexor tendons and the plantar vessels and nerves, as they come through the calcaneal hollow into the sole, and over the first metatarsal bone with the flexor hallucis brevis. The flexor digitorum brevis conceals the flexor accessorius with the tendons of the flexor digitorum longus, and the lateral plantar vessels and nerve. The abductor minimi digiti is in contact, by its deep surface, with the lateral head of the flexor accessorius, the long calcaneo-cuboid ligament, the tendon of the peronæus longus, and over the metatarsus with the flexor brevis minimi digiti.

The **second layer of muscles of the sole** (fig. 87) is constituted by the tendons of the flexor digitorum longus and flexor hallucis longus, together with the flexor accessorius and lumbricals, all of which have been described in the last section.

Relations.—As they lie behind the medial malleolus the long flexor tendons are separated from one another by an interval of about a centimetre in which the posterior tibial vessels and nerve are placed. As the structures pass through the hollow of the calcaneus, under cover of the abductor hallucis, the tendon of the flexor digitorum inclines lateralwards and crosses the tendon of the flexor hallucis, which is continued forwards lying under the fascia upon the flexor hallucis brevis. The tendons of the flexor digitorum longus, together with the flexor accessorius and the lumbricals, are covered by the flexor digitorum brevis, the hinder part of the lateral plantar vessels and nerve being placed between. Deep to these structures are the adductor hallucis (obliquus and transversus), the interossei muscles and the plantar arterial arch.

The **third layer of muscles** (fig. 88) comprises the short flexor and adductors of the great toe and the flexor of the little toe.

M. Flexor Hallucis Brevis.—The short flexor of the great toe springs from an expanded tendinous plate with rather ill-defined attachments, which are moreover subject to considerable variation. The outermost part of the aponeurosis arises from the medial border of the cuboid bone, and the long calcaneo-cuboid ligament, or the calcaneus. The medial part is attached to the middle and third cuneiform bones, along with the offsets from the tibialis posterior to these bones. The cuboid attachment may be wanting. The muscular belly is single behind, but divides in front into two parts, which are inserted by tendinous slips, one into the medial border of the base of the first phalanx in union with the abductor hallucis, and the other into the lateral border in union with the adductors. A sesamoid bone is developed in each of the heads.

The flexor brevis is often inseparably fused with the adductor. It is in great part covered by the abductor hallucis and short flexor of the toes, while the long flexor tendon lies first upon the fibular head and then between the heads as it passes forwards. A slip has been described attached to the metatarsal bone, and sometimes this may be separated from the rest of the muscle and inserted on the whole length of the shaft of the metatarsal, constituting an *opponens hallucis* such as is found in the Simiidae. Occasionally a slip of muscle is observed to arise from the first cuneiform bone and to join the medial head of the muscle at its insertion;

M. Adductor Hallucis Obliquus (fig. 88).—The oblique adductor is a thick fleshy mass which occupies the hollow on the lateral side of the first metatarsal bone. Its superficial fibres arise from the sheath of the peronæus longus through

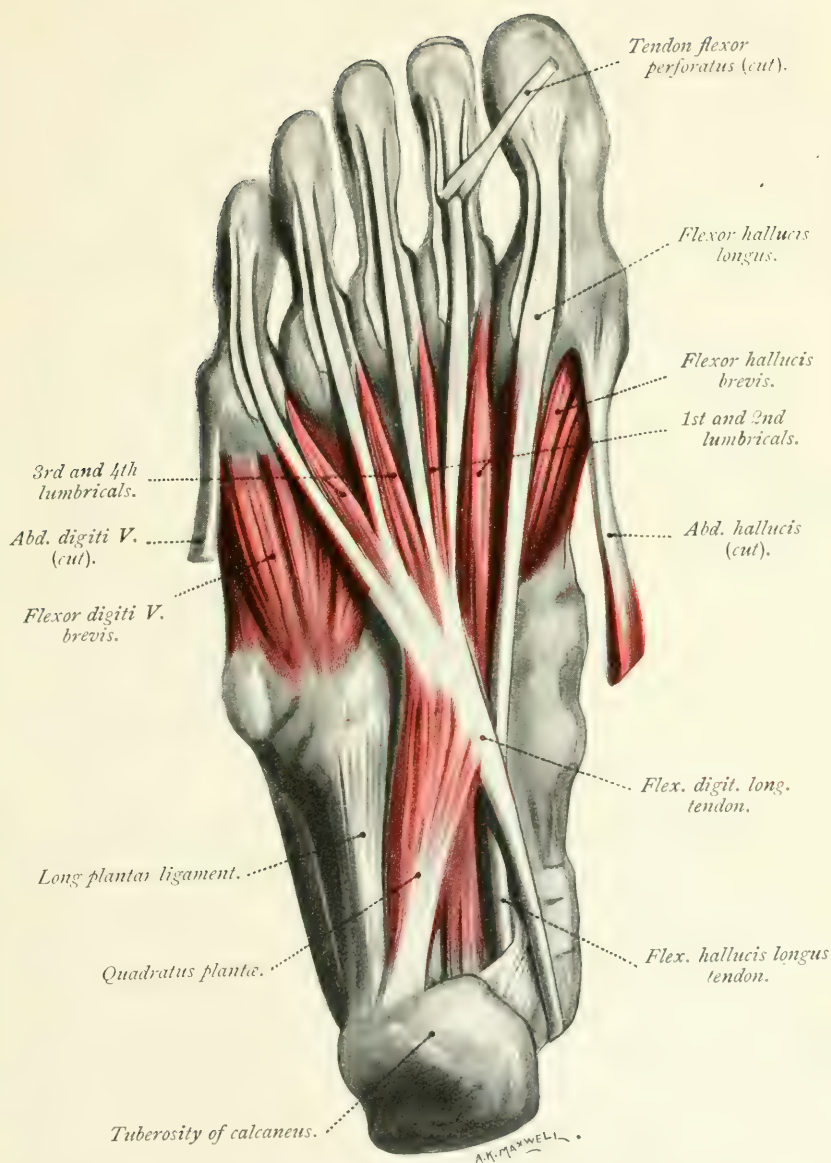


FIG. 87.—MUSCLES OF THE SOLE OF THE FOOT; SECOND LAYER.

which it is fixed to the cuboid bone ; its deeper fibres spring from the third cuneiform and bases of the (second) third and fourth metatarsal bones. Narrowing as it passes forwards, it is inserted, conjointly with the lateral head of the flexor hallucis brevis, into the base of the first phalanx of the great toe. It sends an expansion to the tendon of the extensor muscle.

At its inner side it is connected with the flexor hallucis brevis and is sometimes inseparable from it. Its deep surface rests on the second, third, and fourth metatarsal bones, and the intervening interosseal muscles. The deep parts of the lateral plantar artery and nerve pass medialwards beneath its lateral border.

Varieties.—A slip which has been observed passing from the muscle to the base of the first phalanx of the second or even the third toe, and twice seen as a separate muscular fasciculus (Le Double), is of theoretical interest as representing a vestige of a plantar adductor of the second toe. A slip from the adductor is occasionally found ending on the metatarsal bone of the great toe. This has been held to represent an *opponens hallucis*. The true representation of this muscle is more probably the slip of the flexor brevis described above.

M. Adductor Hallucis Transversus (*transversus pedis*) (fig. 88).—This somewhat variable muscle consists of narrow fasciculi of fleshy fibres, placed transversely under cover of the flexor tendons and crossed by the digital nerves. The fasciculi spring from the plantar metatarso-phalangeal ligaments of the three outer toes and from the transverse metatarsal ligament. Passing transversely towards the great toe they are collected together and inserted into the base of the first phalanx along with the adductor obliquus.

Varieties.—The slip from the little toe is frequently absent. More rarely others of the slips may fail, and absence of the entire muscle has been recorded. The adductor transversus does not correspond strictly to the corresponding muscle in the hand, but only to the occasional fasciculi of that muscle springing from the palmar metacarpo-phalangeal ligaments (p. 154). In the foetal foot the two portions are continuous, but the distal or transverse part travels forwards to assume its definitive position. The central part of the muscle is suppressed in man with the loss of the prehensile power of the hallux. In rare cases a fleshy fasciculus arising from the second metatarsal bone and inserted in union with the adductor represents a vestige of the suppressed part of the muscle (Leboucq).

M. Flexor Brevis Minimi Digiti (figs. 87, 88).—This little muscle, which rests on the fifth metatarsal bone, covered partly by the abductor minimi digiti and partly by the fascia, arises from the sheath of the peronæus longus and the base of the fifth metatarsal bone. It is inserted into the base and lateral border of the first phalanx of the little toe and the plantar metatarso-phalangeal ligament. In the great majority of cases some of the deeper fibres end on the lateral border of the shaft of the fifth metatarsal bone.

This part of the muscle, which is occasionally found as a separate and independent slip, represents an *opponens minimi digiti*. It is often, whether in its independent form or as a portion of the flexor brevis, described as a canonical muscle, but in point of fact it is only an extension of the fibres on to the metatarsal bone. The muscle as a whole is equivalent to the deep part of the opponens of the hand.

The **fourth layer of the sole** (fig. 89) includes the interossei muscles, plantar and dorsal, and with them the tendons of the peronæus longus and the tibialis posterior are sometimes included.

M. Interossei.—As in the hand, so in the foot, the interossei muscles occur in two sets, plantar and dorsal. Only three plantar interossei are normally present, occupying the three lateral interosseous spaces ; but the dorsal series is complete. Owing to the narrowness of the interosseous spaces the primitive plantar position of the interossei muscles is retained to a greater degree than in

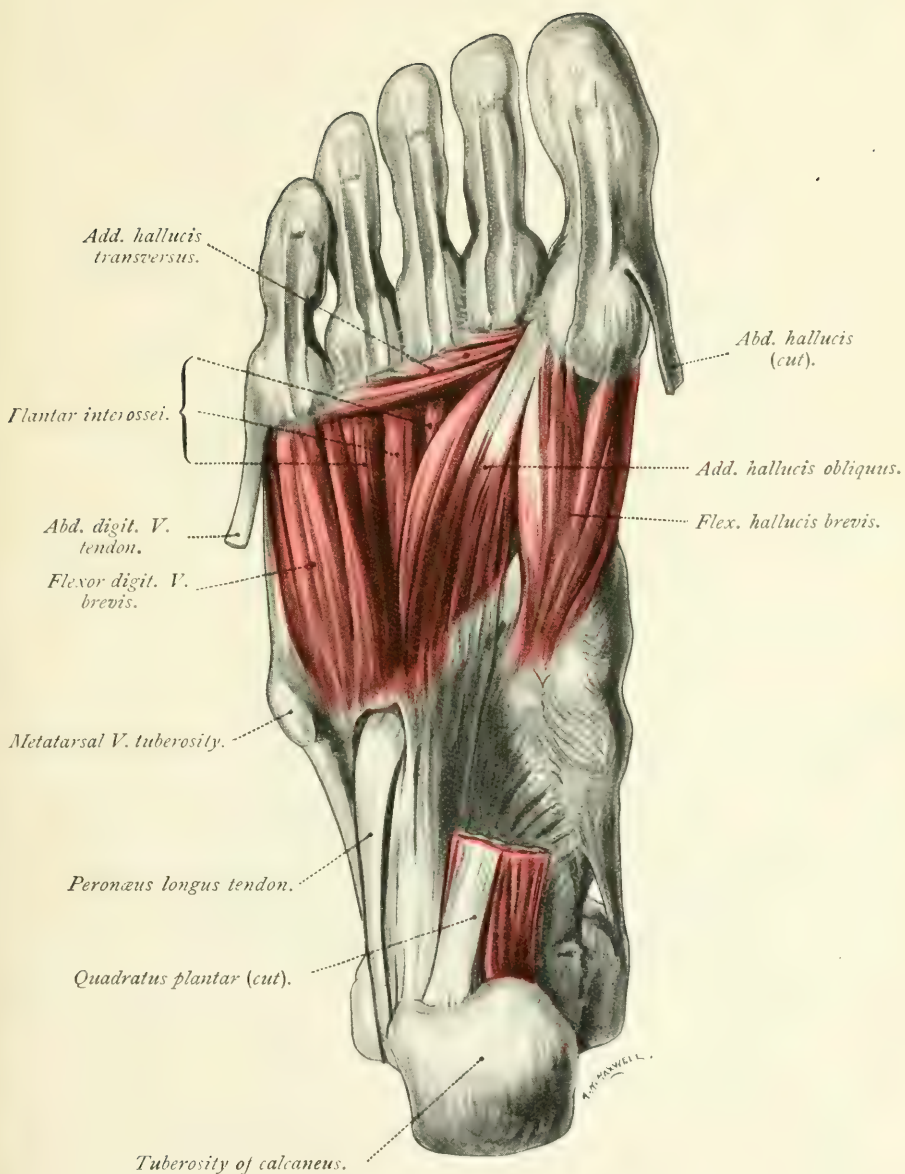


FIG. 88.—MUSCLES OF THE SOLE OF THE FOOT ; THIRD LAYER.

the hand, and the metatarsal bones are concealed in the sole by the muscles. Like the palmar muscles they act as flexors of the first phalanges, but at the same time serve as adductors or abductors of the digits as a whole. In the foot the line to which or from which they act, in this second capacity, runs through the second toe.

The **plantar interossei muscles** (fig. 89) arise from the proximal half of the plantar borders of the shafts and the plantar surfaces of the bases of the third, fourth, and fifth metatarsal bones, and from the sheath of the peronæus longus. They are inserted severally into the medial sides of the first phalanges of the third, fourth, and fifth toes.

The **dorsal interossei muscles** (figs. 89, 90) arise by two heads from the adjacent sides of the two metatarsal bones between which they are placed and also from the bases of these bones. The muscular fasciculi are attached pennately on the two sides of a central tendon, which is inserted into the base of the first phalanx of the toe to which it belongs. The first two are attached one on each side of the second toe; the third and fourth on the lateral sides of the third and fourth toes respectively. At the proximal end of each muscle there is an interval between the two origins which gives passage to the perforating artery as in the hand. The medial head of the first dorsal interosseous muscle is smaller than the others, and arises from the base of the first metatarsal bone and the dorsal edge of the first cuneiform bone. This muscle also receives fibres from a slip sent to it from the tendon of the peronæus longus at its insertion. The third and fourth muscles also receive fibres posteriorly from the sheath of the tendon of the peronæus longus.

The tendons of all the interossei muscles send very thin dorsal expansions to the extensor tendons on the first phalanges, but these are not nearly so well developed as in the hand, and are often not to be made out; indeed their existence is denied by some anatomists.

Bursæ are generally present between the heads of the metatarsal bones, often between the tendons of the plantar interossei muscles and the metatarso-phalangeal articulations, and occasionally beneath the tendons of the second and third dorsal interossei muscles (Gruber).

Nerves to the Muscles of the Sole.—The *abductor hallucis* is supplied from the medial plantar nerve by a single twig, or sometimes two twigs, which, coming off as the nerve leaves the calcaneal hollow, sink into its deep surface at a point approximately 5.5 cm. from the medial malleolus. The *flexor digitorum brevis* also receives one or two twigs which come off the medial plantar as it runs forwards between it and the abductor hallucis, and end in the muscle about 4.5 to 5.5 cm. from the medial malleolus. The *abductor minimi digiti* is supplied by a branch of the lateral plantar nerve which comes off as it lies under the flexor digitorum brevis. It divides into two branches, one for the medial and posterior part which enters close in front of the tuberosity of the calcaneus, and a second which crosses over the deep surface of the muscle to reach its lateral portion. The nerve for the *flexor accessorius* arises from the lateral plantar and ends on the superficial aspect of the muscle near its origin rather to the medial side of the middle line of the sole 5 to 6 cm. from the medial malleolus. The *flexor hallucis brevis* is supplied by a branch of the medial plantar nerve which divides into twigs one for each head. They enter about 8 cm. from the medial malleolus. According to Froshe and Fränkel the lateral head receives a twig from the terminal branch of the lateral plantar, which moreover establishes a loop of connexion with the medial plantar. It is not certain, therefore, from what source the actual motor fibres come. The medial plantar also supplies the first lumbrical muscle. The *flexor minimi digiti*, the *adductors of the great toe*, all the *interossei muscles*, and the *three outer lumbricals* are supplied by the lateral plantar, the first named receiving its twigs from the superficial branch of the nerve, the remaining muscles theirs from the deep branch. The nerve to the flexor brevis minimi digiti enters its muscle at a point between 7 and 8 cm. from the lateral malleolus.

Morphology of the Muscles of the Foot.—Fig. 91 (p. 276) summarises the homologies of the short muscles of the foot. The interossei present no difficulties. A different set of the short deep flexors are utilised as abductors and adductors than in the hand, owing to the fact that the line to which, or from which, they act runs through the second digit instead of the third. The adductors are arranged as in the hand, but it will be noticed that adductor II. is represented as present. It is found in a vestigial form in some cases. The abductor hallucis and abductor minimi

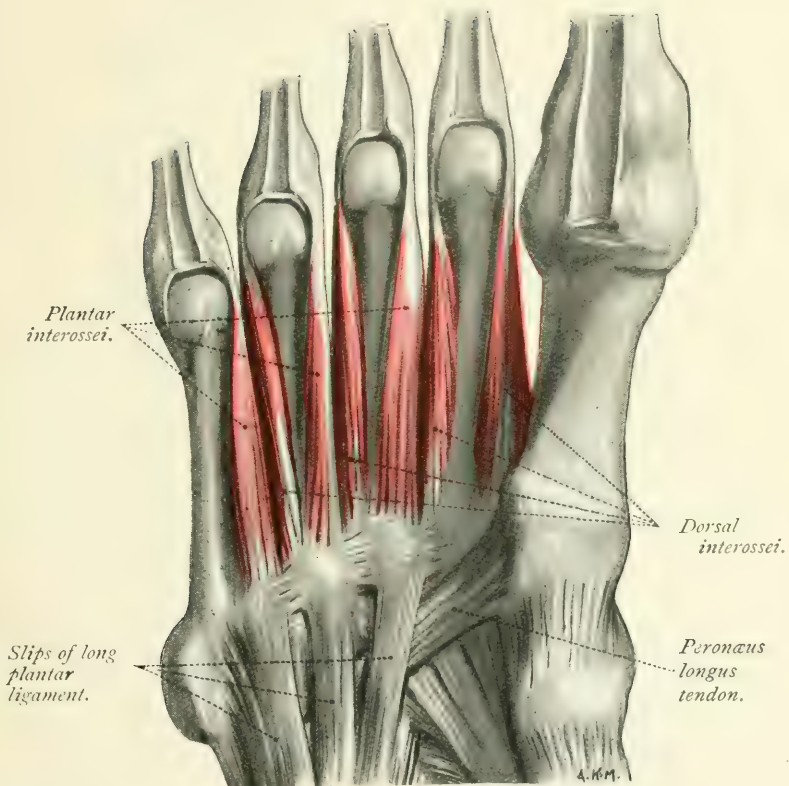


FIG. 89.—MUSCLES OF THE SOLE OF THE FOOT; FOURTH LAYER.

digiti are clearly derivatives of the superficial flexor layer and fall into series, therefore, with the slips of the flexor digitorum brevis. The short flexor of the foot is only in part homologous with the flexor digitorum sublimis in the arm. The primitive plantar fleshy slips have been retained, whereas they have disappeared from the hand. The opponens muscles are not differentiated in the foot owing to the fixity of the first and fifth metatarsal bones. The short flexor of the little finger seen in the hand is suppressed in the foot in man although it can be demonstrated in some lower primates and marsupials (Forster). Perhaps it is represented by the occasional metatarsal origin of the abductor minimi digiti. The so-called flexor brevis of the little toe in man is the fibular head of the deep short flexor of the fifth toe, corresponding to part of the opponens minimi digiti in the hand. The chief difficulty centres in the flexor brevis of the great toe. If we are to judge by the nerve supply it should correspond with the flexor brevis pollicis in the hand, and therefore be a derivative of the superficial flexor layer. Owing to its attachment to the fascia it has acquired a tendinous origin in the sole of the foot outside its morphological limits. The fibular head is closely connected with the adductor and sometimes fused with it; it is absent in some lower forms, *e.g.* lemurs and some marsupials. There seems to be some coalescence of elements, in which case the nerve supply may not be a reliable guide. The muscle in the scheme is represented as arising from the two heads of the first deep short flexor. That the lateral head is the fibular short deep flexor of the great toe is very probable; according to Froshe and Fränkel it is supplied by the lateral plantar nerve. The medial head very possibly includes both superficial and deep elements—in which case it would correspond with the short flexor of the thumb (see p. 156). It must be mentioned, however, that M'Murich refers the fibular head, like the part of the adductor pollicis muscle which closely corresponds with it, to the lumbrical layer.

Actions of the Muscles of the Leg and Foot

(a) **The Muscles which Act at the Ankle-Joint.**—There is considerable variation in the terms which are used to define the movements at the ankle-joint, but those which are probably least open to objection are dorsi-flexion, in which the foot is bent upwards, and plantar-flexion, in which the foot is moved downwards and more into line with the leg. The muscles which effect dorsi-flexion are the tibialis anterior, peronæus tertius, and the long extensors of the toes. The muscles which effect plantar-flexion are the gastrocnemius, soleus, plantaris, tibialis posterior, peronæus longus, and the long flexors of the toes. The plantar-flexor muscles are four times more powerful than the dorsi-flexors, since the line of the body weight lies slightly in front of the transverse axis of movement at the ankle-joint and these muscles are required to preserve the stability of the body in the standing position. The difference between the two groups of muscles is much less in the anthropoids.

The tibialis anterior is the chief dorsi-flexor. Like all the dorsi-flexors it is inserted on the distal side of the mid-tarsal joint, and it has therefore a further action in that it can effect rotatory movements of the foot at that joint. The secondary inversion movements at the mid-tarsal joint are prevented and pure dorsi-flexion obtained, partly by the everting action of the peronæus tertius and the long extensors of the toes and by the synergic contraction of the peronæus brevis muscle. The long extensors of the toes act at the ankle-joint only after they have extended the toes or these have been fixed by their flexor muscles (see p. 147, *cp.* extensors of the fingers).

The chief plantar-flexors are the muscles which act through the tendo Achillis. When the knee is fixed, these muscles take their fixed point above and act entirely on the foot as in walking, running, etc., but in standing their fixed point is at the heel and they then act to prevent the tibia and fibula turning forwards at the ankle-joint in consequence of the incidence of the body weight. The other plantar-flexors are inserted on the distal side of the mid-tarsal joint at which they can effect rotatory movements; but in this respect the tibialis posterior and the peronæus longus muscles are antagonists and in pure plantar-flexion are in equilibrium.

(b) **The Muscles which Act on the Intertarsal Joints.**—In addition to the movements at the ankle-joint, the foot can perform movements of inversion and eversion, in consequence of compound displacements at the posterior and mid-tarsal joints (see Vol. IV., Part I., p. 276). In inversion the foot is adducted, the medial margin is raised and the lateral margin depressed, and the sole of the foot is turned medially; in eversion the foot is abducted, the lateral margin is raised and the medial margin sinks. These movements can be carried out in any position of the ankle, but inversion is most free in plantar-flexion and eversion in dorsi-flexion.

The muscles which effect inversion are the tibialis posterior and tibialis anterior,¹ the latter

¹ The tibialis anterior has been described (Ross, Fick) as having the double action of eversion and inversion, restoring the foot to the mid-position from the extreme of either of these movements.

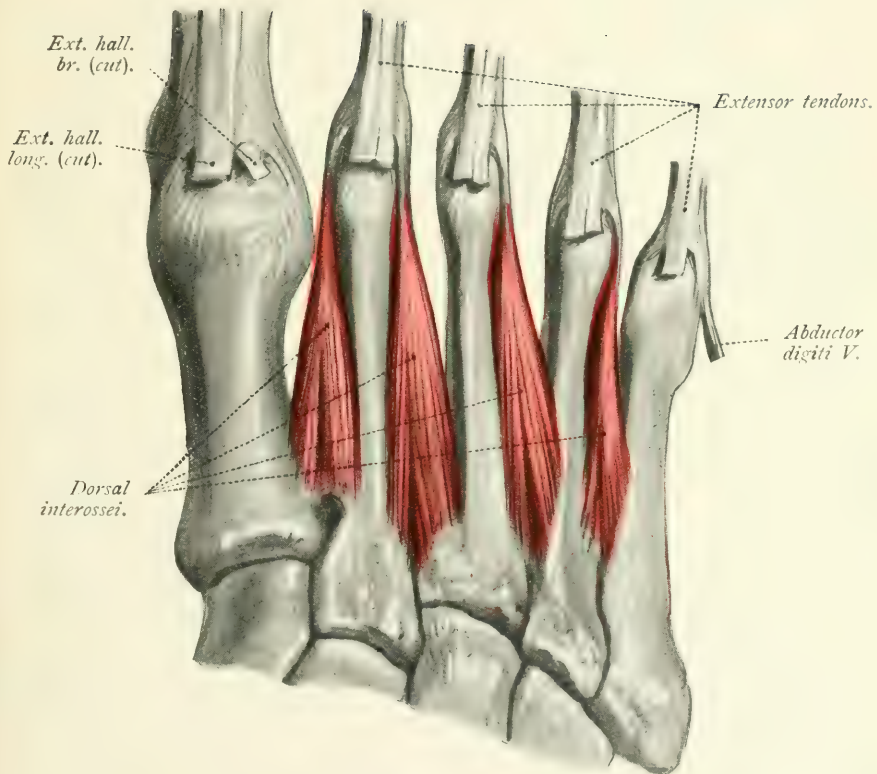


FIG. 90.—MM. INTEROSSEI DORSALES FROM DORSAL ASPECT.

being much the less powerful muscle since the axis of its tendon lies almost in the axis of movement. The muscles which effect eversion are the peroneus longus and brevis, the former pulling the medial margin of the foot downwards and the latter raising the lateral margin. It will be noted that in each of these groups one muscle acts more powerfully in dorsi-flexion and one in plantar-flexion. The tibialis anterior, for example, produces dorsi-flexion and inversion and the tibialis posterior plantar-flexion and inversion; for the one movement, therefore, the muscles are antagonists and for the other they are associated together as prime movers. Among the inverting muscles must be included the gastrocnemius and soleus, for strong inversion of the foot is characterised by plantar-flexion. The long flexor muscles of the toes probably also take part, if one may judge by the fact that the longitudinal arch of the foot is accentuated. The extensor muscles of the toes may assist the tibialis anterior in effecting adduction of the foot, but they can act with only little power. The peroneus brevis is described here as an evertor of the foot. It has also been described as a dorsi-flexor (Winslow) and as a plantar-flexor (Sabatier and most recent writers), while according to Duchenne it can effect both movements from the extreme of either position to the mid-position between them. Its action at the ankle-joint, however, can be of only very secondary importance and of slight power.

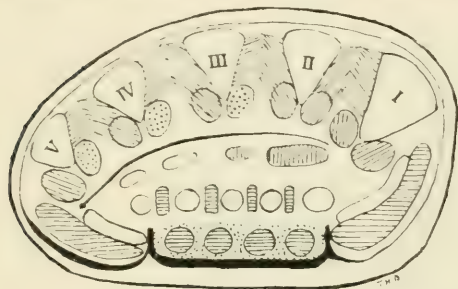


FIG. 91.—SCHEME TO SHOW THE DERIVATION OF THE MUSCLES OF THE FOOT, FROM THE IDEAL GROUND PLAN FIGURED ON PAGE 29.

The plantar aponeurosis is represented as a black line; above this are seen the four heads of the flexor brevis; the tibial marginal mass yields the abductor hallucis, the opponens being absent; the fibular mass furnishes the abductor digiti V., the short flexor of the hand being absent and replaced by the fibular member of the fourth pair of deep short flexors; two adductors are represented, that of the second digit being occasionally present in vestigial form; the short bicipital deep flexors become the interossei muscles, of which the palmar are stippled, the dorsal cross-hatched, in the diagram; to the latter are joined the intermetatarsal fibres; the first pair of bicipital flexors probably provide the flexor hallucis brevis; the fibular member of the fourth pair becomes the short flexor of the fifth toe.

toes are flexed by their proper flexors and by their abductor and adductor muscles, and those of the other toes by the interossei and the lumbrical muscles. The long and short flexors also act after they have flexed their own phalanges, but not with great force. The extensors of all the phalanges of the toes, which are much weaker than the flexors, are the extensor digitorum longus and the extensor pollicis longus and the extensor digitorum brevis, but the short extensor being absent from the little toe, extension of it is performed by the extensor longus alone. The interossei muscles do not act as extensors of the middle and distal phalanges as they do in the hand, since their tendons have not the same dorsal course. The opposite obliquity of the short and long extensor tendons probably enables them to counteract one another, so that when the two act together, as they always do, the toes are extended without deviation.

The movements of abduction and adduction of the toes are lateral deviations from the axis of the second toe. They are of small amplitude compared with the movements of the fingers, and

(c) The Muscles which Act on the Toes.

The movements of the toes are flexion and extension of the individual phalanges, and abduction and adduction of the toes as a whole from the line of the second toe. The flexor muscle of the distal phalanges of the lateral toes is the flexor digitorum longus, which is joined in the sole of the foot by the musculus (flexor) accessorius. The pull of the tendons of the flexor longus is oblique to the long axes of the toes, but by means of the musculus accessorius not only is it strengthened (19 per cent., Haughton) but the pull is directed backwards.¹ The distal phalanx of the great toe is flexed by the flexor pollicis longus, and through its connexion with the long flexor of the toes, the accessorius muscle seems also able to act upon it. The force exerted by the flexor pollicis on the great toe is about three times greater than the flexion forces acting on any of the other toes, an expression of the importance of the great toe in walking. The flexor of the middle phalanges of the four lateral toes is the flexor digitorum brevis, the obliquity of which is opposite to that of the flexor longus, and the flexor longus will also act after it has flexed the distal phalanges.

The basal phalanges of the great and little

¹ If the tendon of the long flexor does not require to be brought into a straight line with the toes, as happens in many animals, the flexor accessorius is absent.

the muscles which produce them act much more as flexors at the metatarso-phalangeal joints than as abductors or adductors; but the lateral spread of the toes is of considerable importance in walking. The abductors are the dorsal interossei, which act on the second, third, and fourth toes—the second toe having two muscles attached to it which abduct to opposite sides—and the special abductor muscles of the great and little toes. The adductors are the plantar interossei which act on the third, fourth, and fifth toes, while the great toe has its special adductor. It has already been stated that the interossei muscles of the foot have no action as extensors of the middle and distal phalanges of the toes.

SYNOVIAL SHEATHS OF THE FOOT

The synovial sheaths of the foot are much less complex than those of the hand, for various reasons: (1) there are fewer muscles passing from the middle to the distal segment of the limb; (2) the tendons have in general separate fibrous sheaths in which they run; (3) there is no communication between the tarsal and the digital sheaths.

Tarsal Sheaths.—The sheaths round the ankle comprise an anterior, a posterior, and a lateral set, under the three annular ligaments.

A. Under the anterior annular ligament there are three sheaths.

1. *Sheath of the tibialis anterior.*—This rises up under the ligamentum transversum well above the level of the malleoli, and accompanying the tendon reaches down to about the level of the talo-navicular joint. It has been seen in continuity with the bursa under the tendon over the first cuneiform bone. Its length varies from 6 to 10 cm.

2. *Sheath of extensor hallucis longus.*—This rises on the tendon as far as a line joining the two malleoli and just above the lower band of the annular ligament. It extends down for about 6 or 7 cm. to the level of the inner cuneiform bone, but it may be continued on to the base of the first metatarsal if it happens to communicate with the independent bursa, or pair of bursæ, which are present on the tendon at this point. One of these sacs is superficial to and the other deep to the tendon, and usually they communicate with one another. As a rare event (Poirier) there may be a small bursa under the tendon over the head of the metatarsal bone.

3. *Synovial sac of extensor digitorum longus and peronæus tertius.*—The investment of the long extensor tendons of the toes rises higher than that of the extensor of the great toe; it reaches a line about 2 to 3 cm. above the ankle-joint passing behind the distal border of the transverse band. It is narrow above and wide below and about 5 to 7.5 cm. long, and ends in a series of small processes on the individual extensor tendons at the level of the navicular bone. A bursa sometimes intervenes between the tendons and the head of the talus, and may communicate with the talo-navicular joint. Bursæ may occur on the tendons as they lie over the distal ends of the metatarsal bones and the first phalanges (Lovell and Tanner). Similar synovial sheaths have been described by Lovell and Tanner on the tendons of the short extensor tendons.

B. *Sheath of the peronæi muscles.*—The two peroneal muscles are surrounded by a common sheath behind the malleolus and on the outer face of the calcaneus under the lateral annular ligament. The sheath extends proximally to a point 2.5 to 3.5 cm. above the tip of the fibular malleolus, where it ends in two small pouches, one related to each tendon. The common sheath, including these pouches, measures about 5 to 6 cm., and ends below by dividing into two at the peroneal tubercle. From this point a sheath extends for about 3 cm. on the peronæus brevis, reaching near to its insertion. The special sheath of the peronæus longus extends only for a short distance on the superficial aspect of

the tendon, but deep to the tendon it is much longer, 5 cm.; it reaches to a point a little in front of the calcaneo-cuboid joint, where it comes close to, or in some cases communicates with, a second sheath nearly 4 cm. long, which lines the fibrous canal by which the tendon is conveyed across the sole of the foot.

C. The *tibialis posterior* and the flexor tendons are each invested by their own synovial coverings in the three compartments under the medial annular ligament.

1. *The sheath of the tibialis posterior* is 7 to 9 cm. in length, commencing about 6 cm. above the tip of the medial malleolus and ending just above the insertion of the muscle. It is generally continuous with the bursa between the tendon and the inferior calcaneo-navicular ligament, but may terminate short of this. There is sometimes a bursa between the tendinous expansion and the navicular and first cuneiform bones.

2. *The sheath of the flexor digitorum longus* does not rise so high above the annular ligament as the last, reaching only about 4.5 cm. above the medial malleolus, but it extends further forward, reaching to the point of crossing with the flexor hallucis longus tendon about the level of the articulation of the navicular and the cuneiform bones. It is about 8 to 10 cm. in length. It sometimes communicates with the sheaths of the *tibialis posterior* and flexor hallucis longus.

3. *The sheath of the flexor hallucis longus* begins just (1 cm.) above the ankle-joint, and lining the groove on the talus and under the sustentaculum tali it follows the tendon, passing with it deep to the long flexor of the toes, and ends where the tendons interchange fibres. Here there may be a communication between the two sheaths. The sheath of the flexor of the great toe is rather longer than that of the common flexor, measuring from 9 to 12 cm.

All the tendons enumerated above have continuous mesotendons, with the exception of the distal part of that of the *peronæus brevis* and the tendon of the *tibialis posterior* which lie free in their sheaths. This circumstance is related to the relatively restricted range of movement of the foot and toes as compared with the hand and fingers.

Digital Sheaths.—The flexor tendons within the flexor sheaths on the toes are surrounded by synovial investments which have the same general characters as those studied in the hand. The sheath of the tendon of the great toe reaches backwards a distance of 2 or 3 cm. on the shaft of the first metatarsal bone, but the others do not extend beyond the level of the heads of the metatarsal bones.

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THE following list of publications is not intended to be in any sense exhaustive. Only a collection of the more recent books, memoirs, and papers, and some of the older important publications are included. The aim in compiling the list has been to furnish the reader with such references as will introduce him to the literature of the several branches of the subject of myology. The references are classified according to the subject matter of the publications cited, and the classes have been made as small as possible in order to avoid the necessity of printing at length the title of each paper.

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